#448

Y/EX-23

Y-12

OAK
RIDGE
Y-12
PLANT

UNION
CARBIDE

Mercury at the Y-12 Plant

A Summary of the 1983 UCC-ND Task Force Study

CLEARED FOR

PUBLIC RELEASE

DM for PTO

OPERATED BY
UNION CARBIDE CORPORATION
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

Y/EX-23

Mercury at the Y-12 Plant

A Summary of the 1983 UCC-ND Task Force Study

November 1983

Oak Ridge Y-12 Plant
P.O. Box Y, Oak Ridge, TN 37831

Operated by Union Carbide Corporation
for the
U.S. Department of Energy
under Contract No. W-7405-eng-26

UCC-ND Mercury Task Force Members and Support Staff

John W. Arendt
Separation Systems Division
Oak Ridge Gaseous Diffusion Plant

Lucinda L. Ball
Industrial Engineering Division
Oak Ridge Y-12 Plant

Bobbie N. Collier
Information Division
Oak Ridge National Laboratory

Richard W. Counts
Quality Division
Oak Ridge Y-12 Plant

Charles D. Doty
Operating Contractors Project Office
Oak Ridge Gaseous Diffusion Plant

Elizabeth A. Fraley
Finance, Materials, and Services Division
Oak Ridge Y-12 Plant

Mary J. Goss
Finance, Materials, and Services Division
Oak Ridge Y-12 Plant

James G. Grimes
Technical Services Division
Oak Ridge Gaseous Diffusion Plant

Charlotte E. Johnson
Finance, Materials, and Services Division
Oak Ridge Y-12 Plant

George E. Kamp
Health, Safety, and Environmental Affairs
Oak Ridge Y-12 Plant

G. Ruth Lassiter
Finance, Materials, and Services Division
Oak Ridge Y-12 Plant

Victor W. Lowe
Quality Division
Oak Ridge Y-12 Plant

Lowell L. McCauley
Operating Contractors Project Office
Oak Ridge Gaseous Diffusion Plant

Hershel V. McCollum
Auditing Division
Union Carbide Corporation—Nuclear Division

Ronald J. McElhaney
Product Certification Division
Oak Ridge Y-12 Plant

Wilbert D. Minter
Finance, Materials, and Services Division
Oak Ridge Y-12 Plant

John M. Napier
Development Division
Oak Ridge Y-12 Plant

Ricky J. Roberson
Industrial Engineering Division
Oak Ridge Y-12 Plant

Theresa Santak
Operating Contractors Project Office
Oak Ridge Gaseous Diffusion Plant

Denise D. Schmoyer
Quality Division
Oak Ridge Y-12 Plant

David W. Smith
Metal Preparation Division
Oak Ridge Y-12 Plant

Ralph R. Turner
Environmental Sciences Division
Oak Ridge National Laboratory

Charles M. West
Health, Safety, and Environmental Affairs
Oak Ridge Y-12 Plant

William J. Wilcox, Jr., *Chairman*
Assistant to the President
Union Carbide Corporation—Nuclear Division

Contents

Foreword

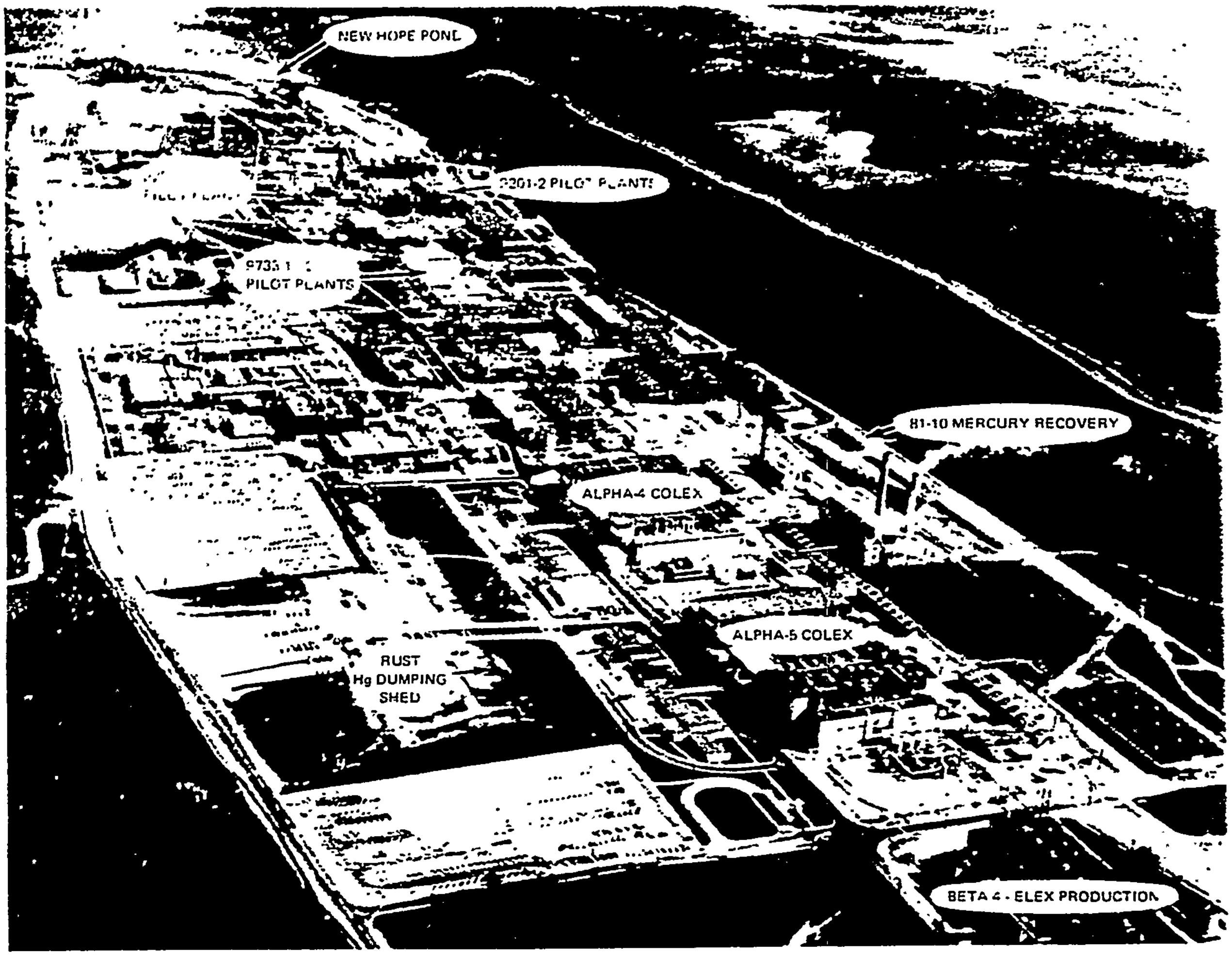
This document summarizes the work done this past summer by the UCC-ND Task Force asked to study the use of mercury in the lithium isotope separation work at the Oak Ridge Y-12 Plant from 1950 to 1963. Aspects of special interest to the task force in their study were worker health, the environment, accountability, and losses. Gordon Fee, Y-12 Plant Manager, appointed the task force on May 20, 1983.

Some of the work of the task force was completed before the congressional hearing of July 11, 1983, and was summarized in the testimony of Chester R. Richmond, an Associate Director of the Oak Ridge National Laboratory. That testimony is included as Appendix A of this report. Writing of the formal report of the task force was not completed until August, and it includes considerable process details and documentation that are classified Secret. A version of the report with that classified information deleted is now being prepared for release.

Even the unclassified version with deletions, however, is quite detailed, and those persons interested in the study may find its 417 pages ponderous. This report, written primarily for Y-12 employees, is intended to fill the need for a summary of the more important findings of the task force in a form both more accessible and more usable than the detailed version. Moreover, since the August report, some important information has developed that is of much interest but that has not yet been prepared for formal technical reporting. That new information is presented here. This report was prepared by editing and expanding the executive summary of the August report, adding several key illustrations and data summaries, and updating the work on the sampling and analyses of sediments in the Watts Bar and Chickamauga lakes. ■

William J. Wilcox, Jr.

Y-DWG 83-816



Looking east, the Oak Ridge Y-12 Plant in about 1963 at the time of completion of the Lithium Isotope Separation Program [code name, Alloy Development Program (ADP)]. The primary production buildings were Alpha-4 and Alpha-5 (Buildings 9201-4 and 9201-5), which used the Colex process (column exchange). The mercury-receiving operation was carried out in an open-air shed (see lower left of photograph) operated by Rust Engineering for the U.S. Atomic Energy Commission on the site of the current Building 9103.

History

The large-scale use of mercury at the Y-12 Plant was associated with the production of lithium enriched in the light isotope form, lithium-6, for use in hydrogen or thermonuclear weapons. The heavier lithium-7 isotope form is more abundant in nature. The initial request to Y-12 to develop processes for lithium isotope separation came in 1950, and a major production plant expansion was undertaken in 1953. In the remarkably short period of 15 months, two large production facilities were designed and built, and the first units were put into production in January 1955. Production stopped in 1963.

The process that made this effort a success is called Colex, the name being a contraction of "column exchange." It is a chemical exchange process in which lithium isotopes are partially separated as they transfer between two chemical phases. One of these phases is an aqueous solution of lithium hydroxide, and the other phase is a lithium amalgam, a solution of lithium in mercury. Many millions of pounds of mercury were essential to the project. Directives signed by President Eisenhower made the mercury available from the national stockpile. It is this mercury used for the Colex process from 1955 to 1963 that is the source of today's concerns.

When the need was recognized for large-scale separation of the lithium isotopes, no process was available to accomplish that separation. Figure 1 gives a chronological summary of the progress made and processes used since 1950. The first successful laboratory separation was achieved using the Elex process—an electrically driven chemical exchange process akin to a process used in industry (in chlor-alkali production facilities) for making chlorine and sodium hydroxide. A production-scale plant was operated in Building 9204-4. A view of some of the equipment used in this process is given in Figure 2. By contrast, the Orex process, in which an organic solution of lithium was exchanged with lithium amalgam, never got beyond the pilot-plant scale. Research and development on the Colex process began in 1951 and proved very successful, resulting in the shutting down and dismantling of work on the Orex and Elex processes. Figure 3 shows the facilities in which lithium isotope separation work was done. Meeting of production targets permitted shutdown of Building 9201-5 in 1959 and of Building 9201-4 in 1962. The 9201-5 plant was started up again for a six-month campaign in 1963, and then all production ceased. The Colex equipment for 9201-5 was dismantled and disposed of during 1965 and 1966, but the Colex equipment in 9201-4 remains. Plans are to remove that equipment within the next few years. ■

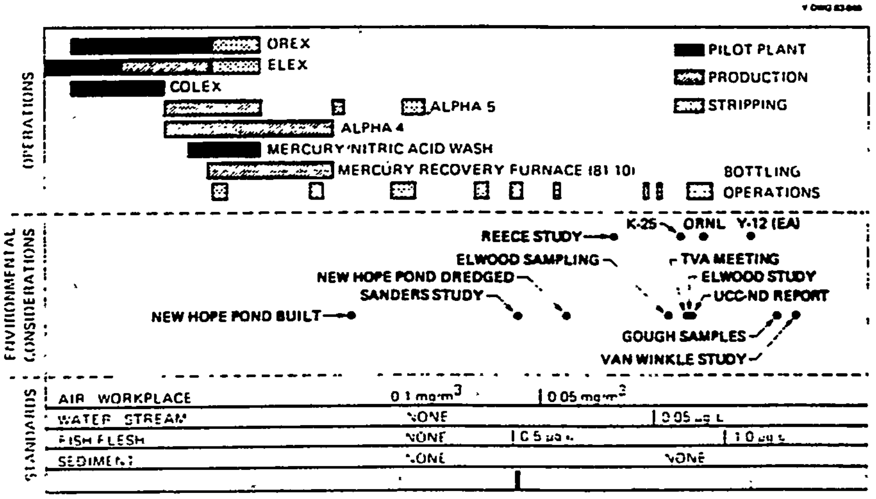


Figure 1. Chronology of lithium isotope separation operations at the Y-12 Plant and related information.

Y/PH-12503

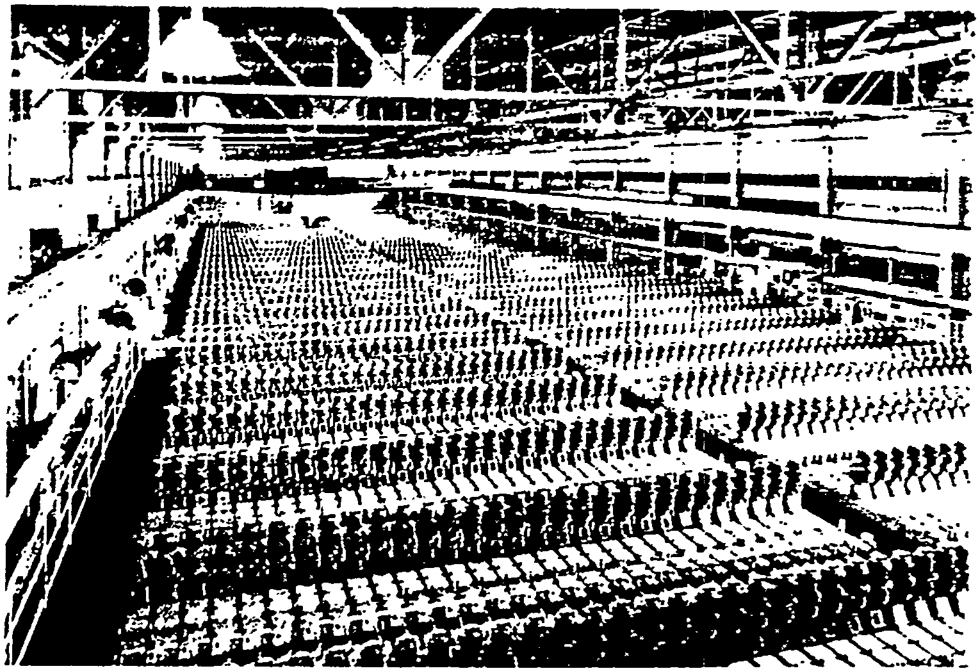


Figure 2. Partial view of an Elex (electrical exchange) cascade in 1955.

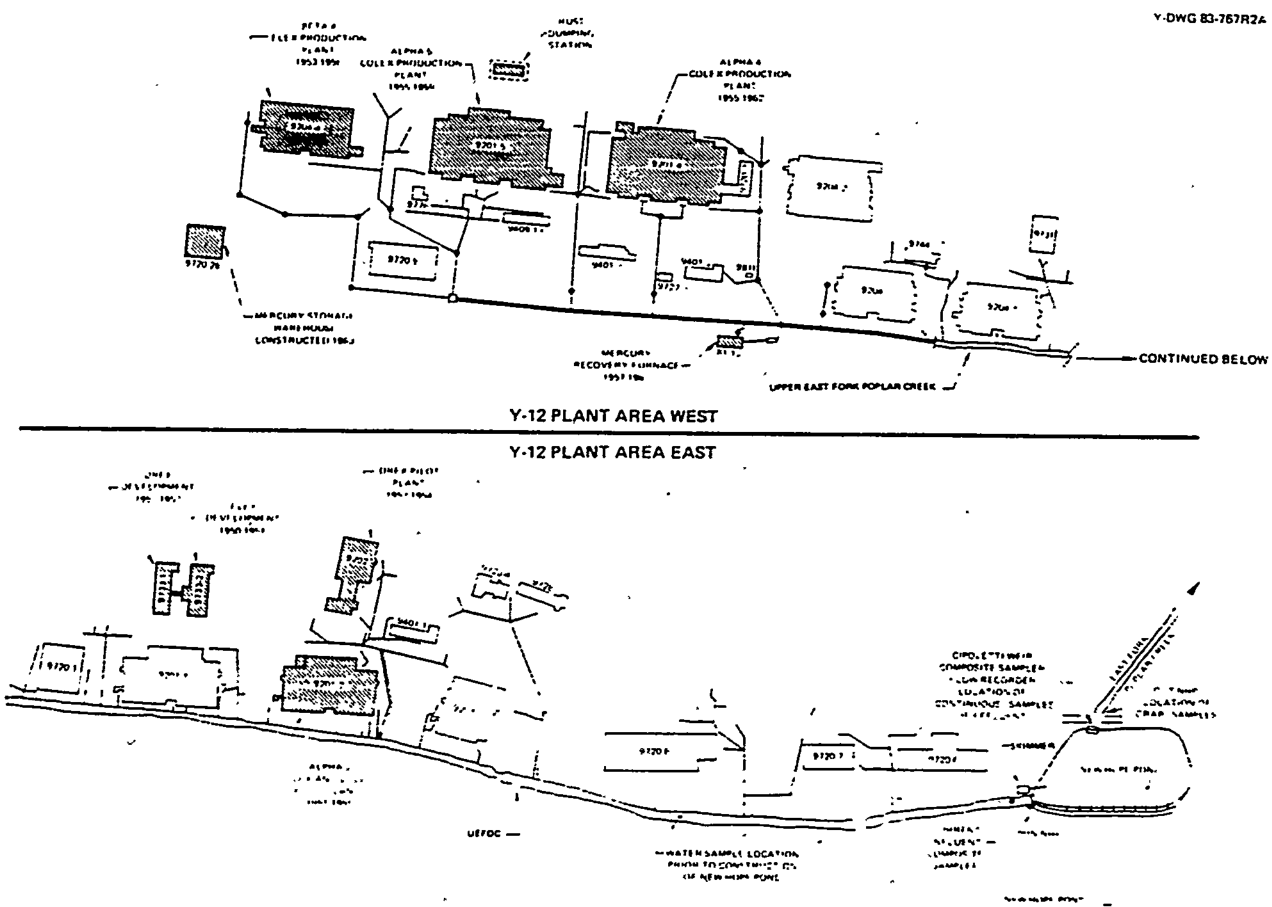


Figure 3. Lithium isotope separation facilities at the Y-12 Plant, 1950–1963.

Colex Process

The process is based on the fact that the lithium-6 isotope becomes concentrated to a slightly greater extent in the mercury phase than does the lithium-7 isotope. If a solution of lithium hydroxide in water is made to contact a solution of lithium metal in mercury, an exchange of the lithium will occur such that the lithium-6 concentration in the amalgam will be a little higher than in the aqueous phase. This process is repeated many times so that useful degrees of enrichment are achieved as well as significant quantities of products. The tails (high lithium-7) reflux stream is shown on the left of Figure 4. In this process step, lithium from the column aqueous waste stream is plated into clean mercury to form lithium amalgam, which is then pumped to the column cascade. Some is withdrawn and stored as the process "waste."

On the other end of the cascade, shown to the right in Figure 4, the product-enriched lithium-6 is withdrawn during the product reflux step. This step involves decomposing the lithium amalgam coming from the "top" of the cascade (i.e., the bottom of the last column). Decomposition is effected by contacting the amalgam with water, resulting in a solution of lithium hydroxide in water and mercury. Some of the product solution is refluxed back to the cascade.

Some of the auxiliary process equipment used to purify the mercury for the Colex process is shown in Figure 5. The amalgam formation area (code name, Absorber Room) of one of the Colex cascades is shown in Figure 6. In these long cells (arranged perpendicular to the direction the camera is facing), lithium is forced into mercury by an electric current to form lithium amalgam. ■

Y-DWG 83-1591

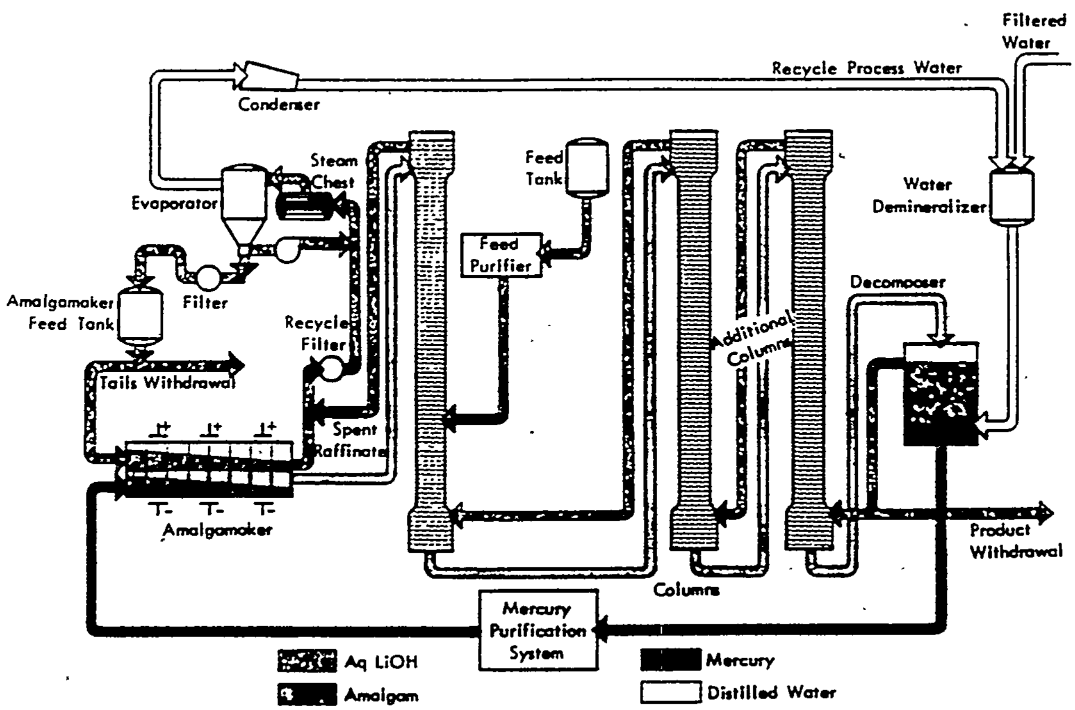


Figure 4. The Colex process for lithium isotope separation.

Y/PH 102451

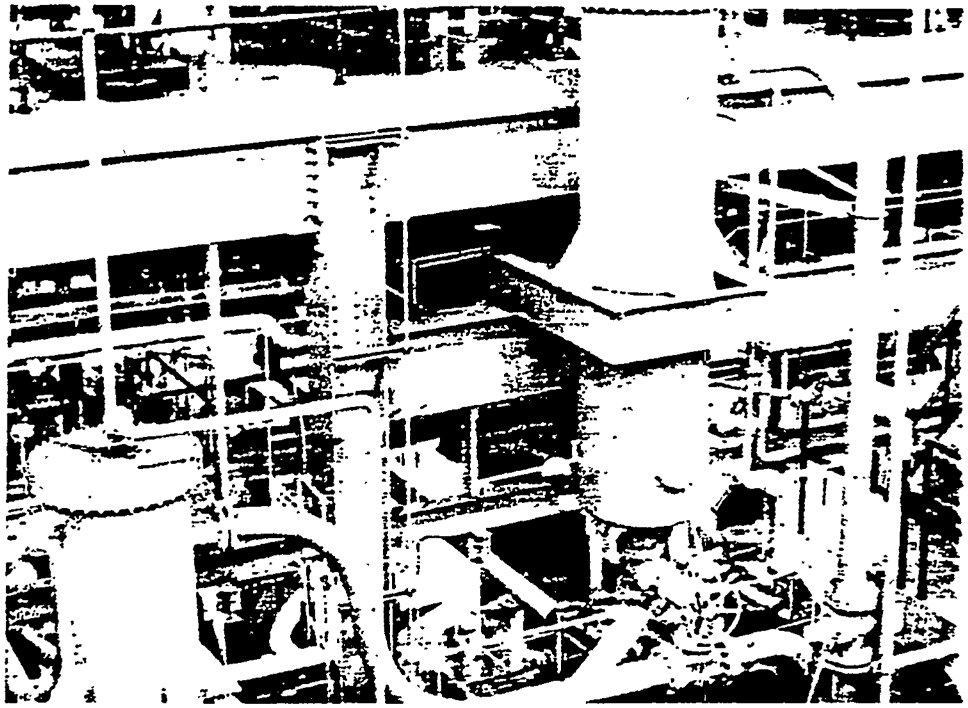


Figure 5. A mercury–nitric acid purification system used in the early years of Colex operations to remove impurities from the mercury. It was the source of most of the mercury lost to the creek.

ORO-55-131

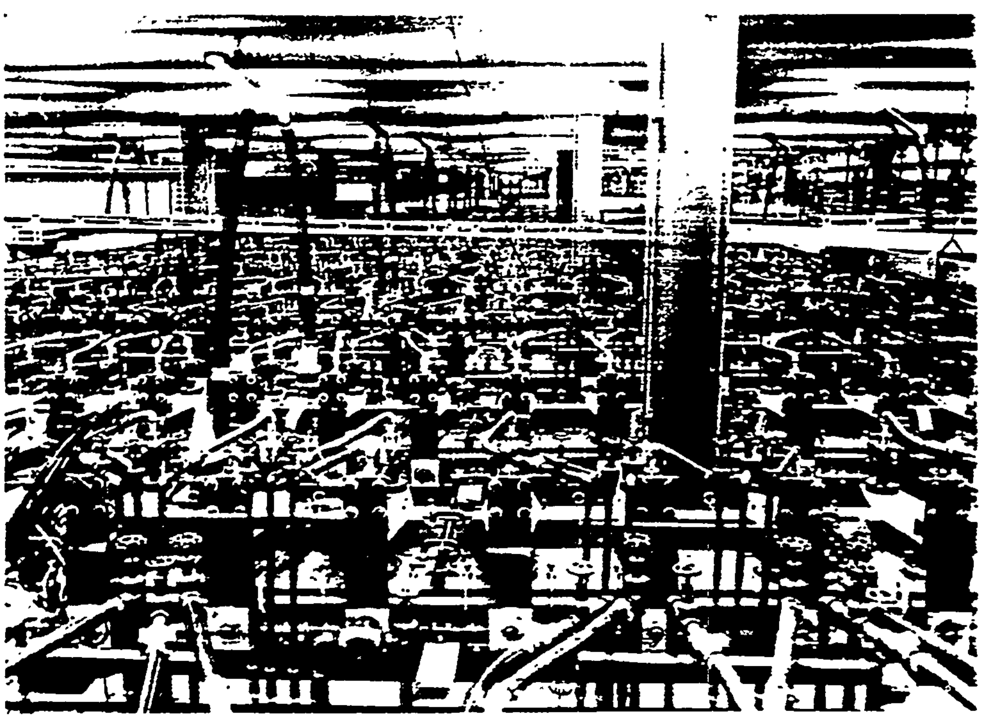


Figure 6. The amalgam formation area for a Colex cascade.

Worker Health

Industrial hygiene. Mercury toxicity was a major concern of the U.S. Atomic Energy Commission (AEC) and Y-12 Plant managers and industrial hygienists as they prepared in 1953 and 1954 for Colex operations. (In the chronology of mercury standards given in Table 1, note the upper limits in effect at the Y-12 Plant in 1952.) The process was to involve thousands of workers, and programs to cope with the recognized hazards of breathing mercury vapor were instituted before the cascades went into operation. Industrial hygiene programs were already in operation because of the need to protect worker health in the laboratory, in the pilot plant, and in production programs under way in 1950–1954 on Orex and Elex as well as on Colex. But the scale of operations was to be expanded greatly and much larger quantities of mercury were to be involved in Colex than in any of the previous operations.

The floors of the Colex buildings were modified so that floor drains emptied into special tanks in the basement. These tanks were designed so that mercury could be recovered before wastewater (e.g., mop water) was released to other water-collecting sumps located inside and outside the buildings before entering the creek. These precautions were taken because it was recognized that Y-12 was pioneering an entirely new process using pumps and other equipment that had never before been used for such applications. The engineers anticipated frequent maintenance and operational problems during the start-up of the new processes. The first year of production, 1955, was indeed a troublesome one. Many problems developed with the equipment. Pumps and valves needed to be serviced often, the process equipment was full of mercury, and spillage or leakage of mercury during normal maintenance operations was expected and encountered. The spills and leaks were accommodated by special containers and procedures.

The mercury concentration in the workplace air was monitored frequently. (In 1956 alone 280,000 air readings were taken.) Figures 7 and 8 provide air sampling data collected in Buildings 9201-4 and 9201-5, respectively, between 1955 and 1961. Figure 9 shows a collection of air sampling data taken at the Y-12 Plant between 1956 and 1971. During cascade start-up in 1955, many mercury concentration readings of the workplace air were higher than the then recommended standard of 0.1 mg/m^3 (0.05 mg/m^3 now).

A urinalysis program started in 1953 provided an additional check on worker exposures to mercury. During the time that elevated concentrations of mercury in air were encountered in 1955, the urinalysis data also showed elevated readings (see Figure 10), although the average for all workers in the urinalysis program never exceeded the

Table 1. Recommended guidelines for mercury concentrations, 1943–1973

Year	Organization	Guideline or standard: Air (mg/m^3)	Guideline or standard: Urine (mg/L)
1943	American National Standards Institute	0.1	
1946	American Conference of Government Industrial Hygienists	0.1	
1952	Y-12 Plant	0.1	0.3
1957	University of Rochester recommendations	0.1	0.3
1971	American National Standards Institute	0.1	
1971	American Conference of Government Industrial Hygienists	0.05	
1972	American National Standards Institute	0.05	
1973	National Institute for Occupational Safety and Health	0.05	
1973	Y-12 Plant	0.05	0.3

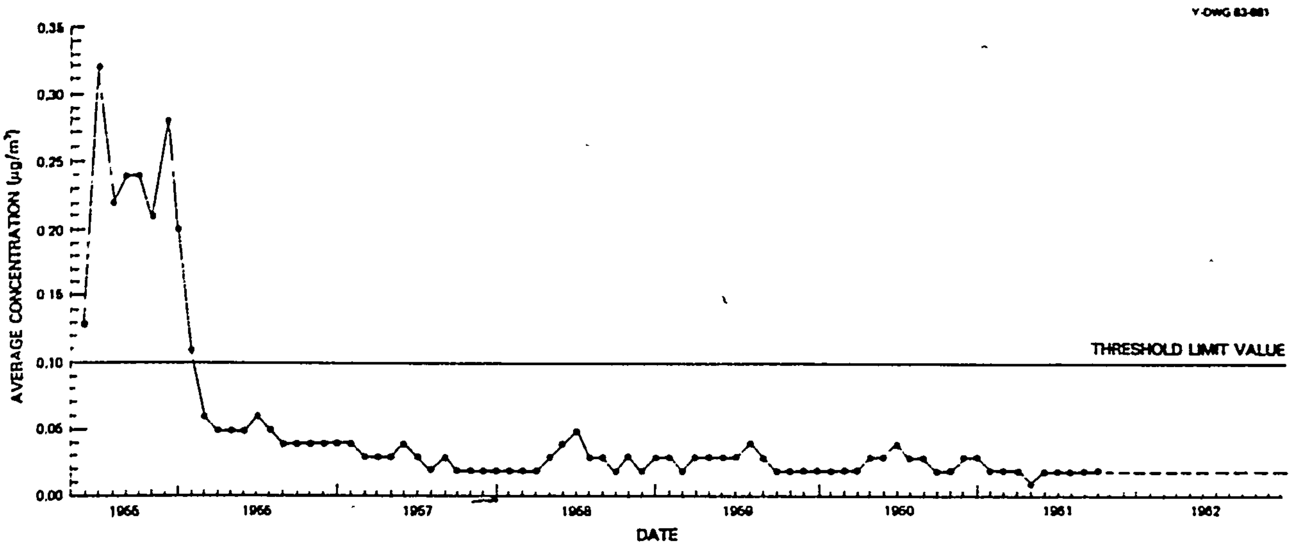


Figure 7. Mercury concentration in Building 9201-4 workplace air (average of air samples by month).

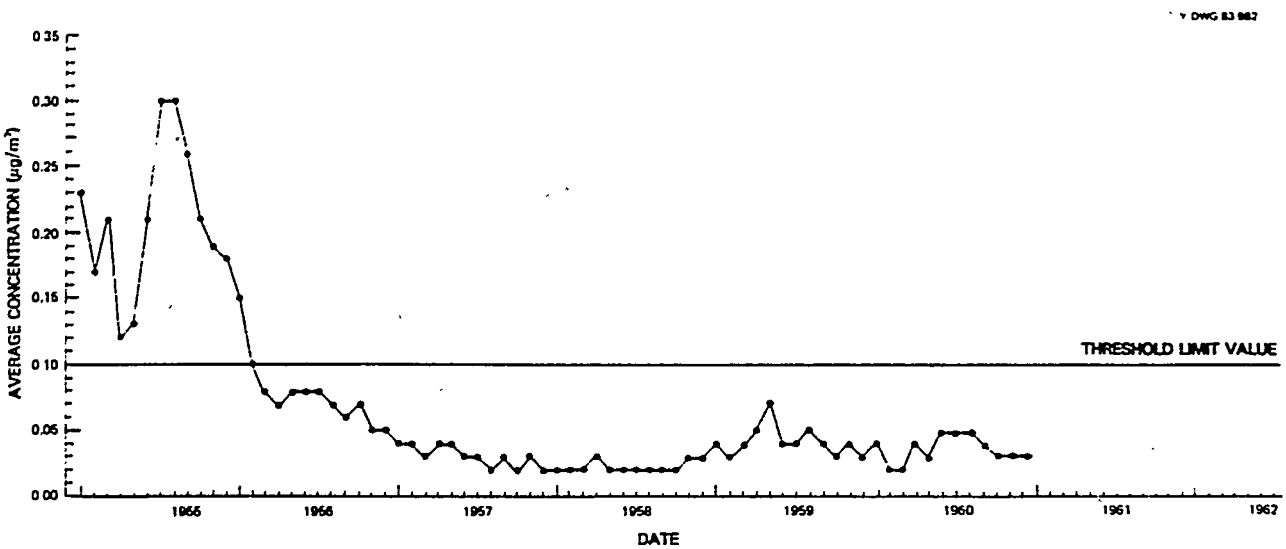


Figure 8. Mercury concentration in Building 9201-5 workplace air (average of air samples by month).

recommended maximum urinalysis mercury value (then and now) of 0.3 mg/L (Figure 11). Still, approximately 200 to 300 workers had readings that did exceed the 0.3-mg/L level during the latter part of 1955 and the early part of 1956. Figure 12 shows the number of people whose urinalysis mercury value exceeded the standard during the period 1953–1971. When a worker's urinary mercury or albumin values remained at a high level for several specimens, the individual involved was reassigned to another work area until the urinalysis mercury or albumin values dropped to the normal level; the employee then returned to work in the mercury area. Approximately 70 people were involved in temporary reassignments of this nature. The amount of time necessary to clear mercury from the body is indicated by the data given in Figure 13.

In addition to the air sampling and urinalysis programs, a special medical surveillance program provided that clinical examinations of mercury

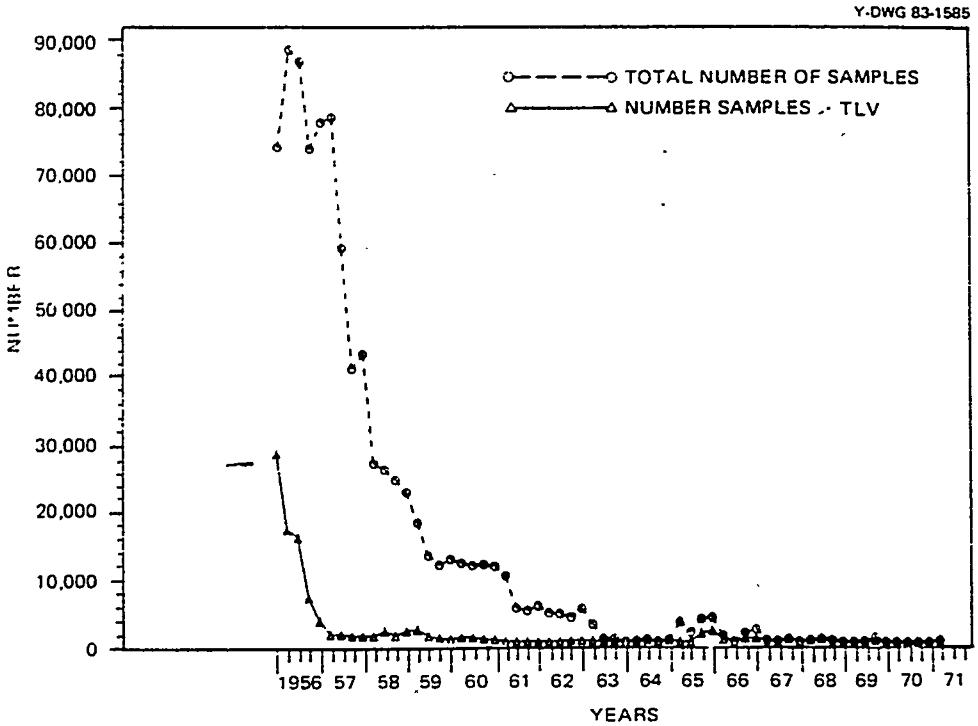


Figure 9. Routine environmental air samples for the Y-12 Plant [plot of the total number of samples taken and the number exceeding the threshold limit value (TLV) of 0.1 mg of mercury per cubic meter of air].

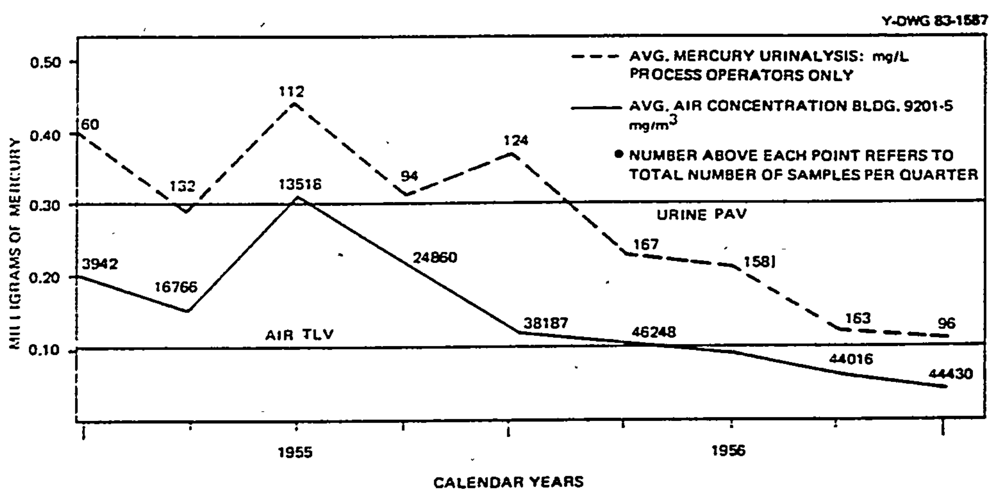


Figure 10. Y-12 data showing the correlation between mercury vapor in the workplace air and mercury in workers' urine samples. (The correlation had been observed elsewhere.) The recommended mercury levels of 0.1 mg/m^3 for air and 0.3 mg/L for urine came from studies of the felt hat industry conducted in 1941 by the U.S. Public Health Service. Information gathered here supports the choice of 0.3 mg/L in urine as a useful indicator value.

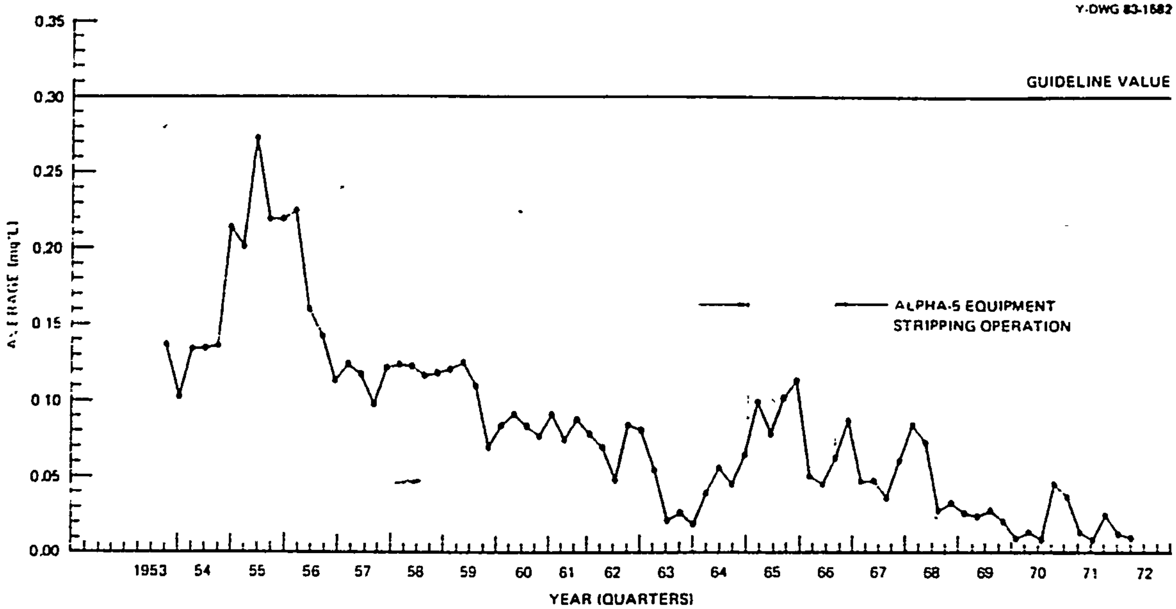


Figure 11. Averages of urinalysis results for all mercury workers per quarter.

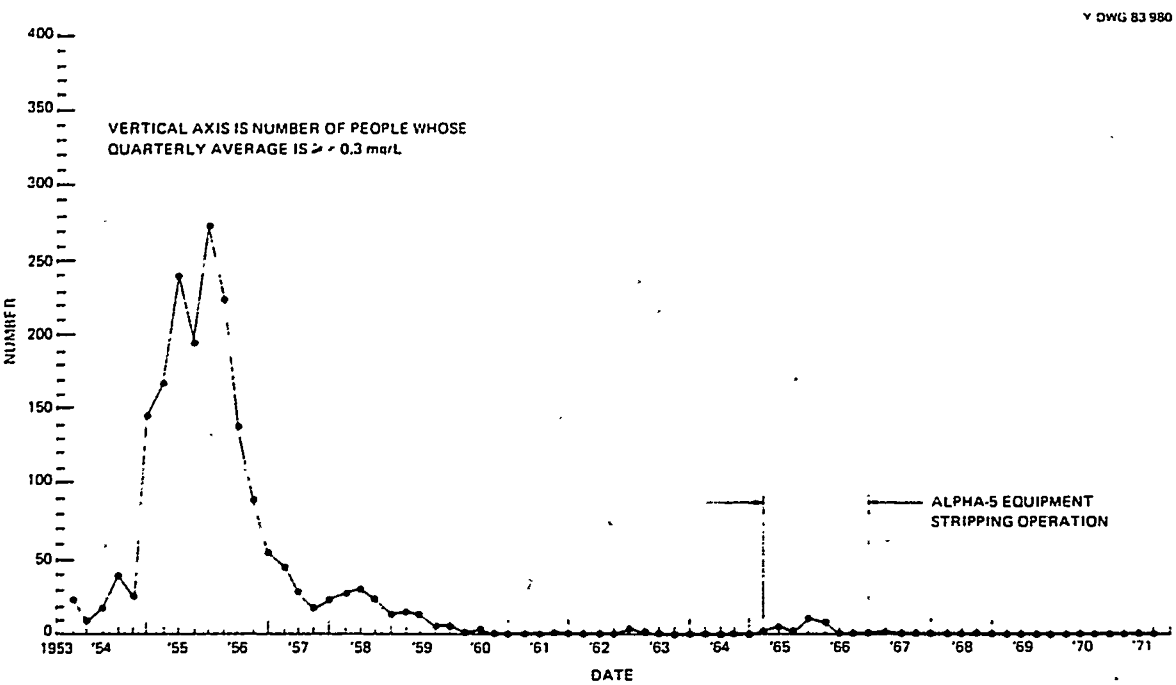


Figure 12. Number of persons whose quarterly urinalysis mercury value exceeded the recommended standard of 0.3 mg/L between 1953 and 1971.

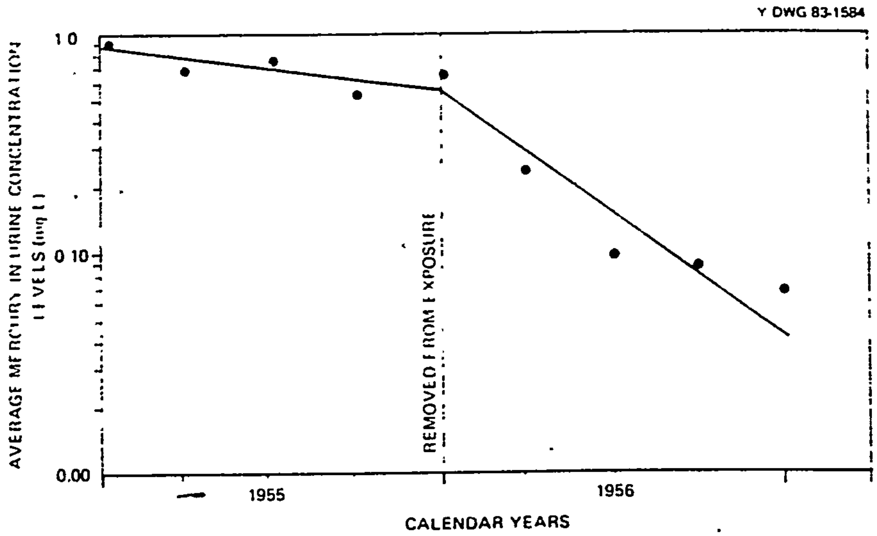


Figure 13. Data from a Y-12 Medical Department report (1957) indicating the time necessary to clear mercury from the body. The points are averages of urinalysis sample data on about 24 employees who were removed from their workplaces in January 1956 because of elevated urinalysis mercury values. They had been exposed to mercury 12 to 15 months prior to that time and showed decreasing levels during 1955. It took about 3 months for urinalysis values to reach 0.3 mg/L and about 9 months to reach 0.1 mg/L.

workers be performed every six months. Persons with a history of albuminuria, kidney problems, or hypertension were screened out and not allowed to work with mercury.

Toward the latter part of the Colex start-up during 1955, AEC and Y-12 management undertook a crash program to bring the workplace mercury vapor down to acceptable levels. The program involved various efforts such as studies of paints and technical studies of substances that could reduce vapor pressure and agents that could dissolve tiny mercury droplets. Building design changes included renovation of the ventilation systems and installation of large fans in the end walls to provide more fresh air (Figure 14). Other changes included major new housekeeping programs and the installation of a special house-vacuum system for mercury pickup. A study of commercially available respirators and cartridges resulted in the adoption in the spring of 1956 of a different (Mersorb) cartridge and renewed emphasis on the use of respirators. The effectiveness of these and other efforts is documented in the historical record of air concentrations, which shows that levels of mercury vapor in air were dramatically reduced and under control by March 1956 and remained under control during the next seven years of operation.

1974 Medical checkup. In 1974 a consultant of the National Institute for Occupational Safety and Health, Dr. Z. Bell, reviewed the Y-12 data on mercury worker exposure. He picked out 50 of the original workers, most of whom had received high exposures (based on urinalysis), and asked the Y-12 medical staff to examine them according to a protocol that he suggested. Examination of each of the 23 employees still on the payroll revealed no symptoms of mercury poisoning. Another interest in this exercise was in looking for mercurialentis, a harmless discoloration of the eye. Only one case was observed and this in a worker not exposed to high levels of mercury.

1983 Mortality study. In 1983 Oak Ridge Associated Universities (ORAU) conducted, at the

Y/PH 102455

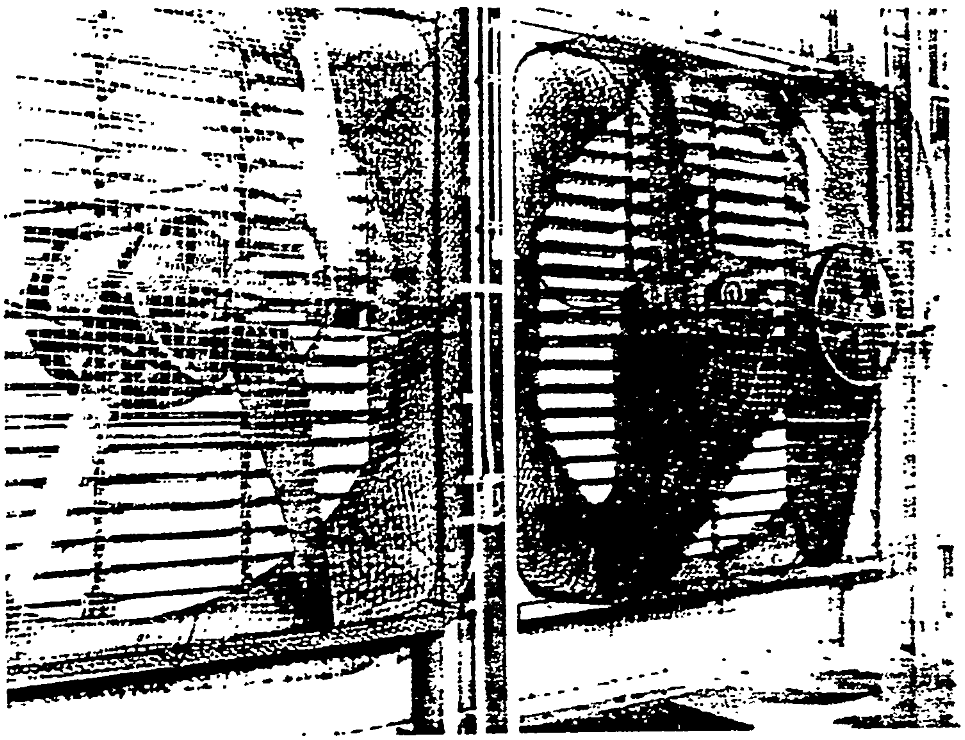


Figure 14. New exhaust system added to Building 9201-5 during 1955.

request of the task force, a preliminary epidemiological study* of the mortality of the Y-12 mercury worker population by comparing this group (1477) with the other Y-12 workers (4920) and then comparing both groups with the U.S. population as a whole (Table 2). The purpose was to determine whether there is any evidence to suggest that the death rates are higher for the employees who worked in the Y-12 mercury-exposure areas than for other Y-12 employees. No such evidence was found. Death rates for mercury workers as a group were 93% of the rates for the U.S. population group to which they were compared, while the death rates for the Y-12 nonmercury workers were 90% of the rates for the U.S. population. The statistical confidence intervals for each category overlapped considerably, and no significant difference was found. Similarly, no difference was found between the Y-12 mercury workers and the other Y-12 workers in the death rates due to cancers, diseases of the central nervous system, respiratory diseases, or chronic nephritis.

*This study is described as preliminary because only data on deaths through 1973 were available for inclusion. Plans are to update this study in the fall of 1983.

1983 Medical checkup. As a supplement to the regular medical program, Y-12 initiated planning in August 1983 for a special checkup for Y-12 mercury workers. In addition to dealing with the concerns that some of the workers may have about their health, the checkup offers an opportunity, perhaps unique, to study a fairly large group of mercury workers 20 years after well documented exposures (27,000 urinalyses on 2450 people). Although the studies elsewhere of people with similar degrees of exposure show no organic effects, the Y-12 group is larger and has a longer-term after exposure. The most common symptoms of chronic metallic mercury toxicity

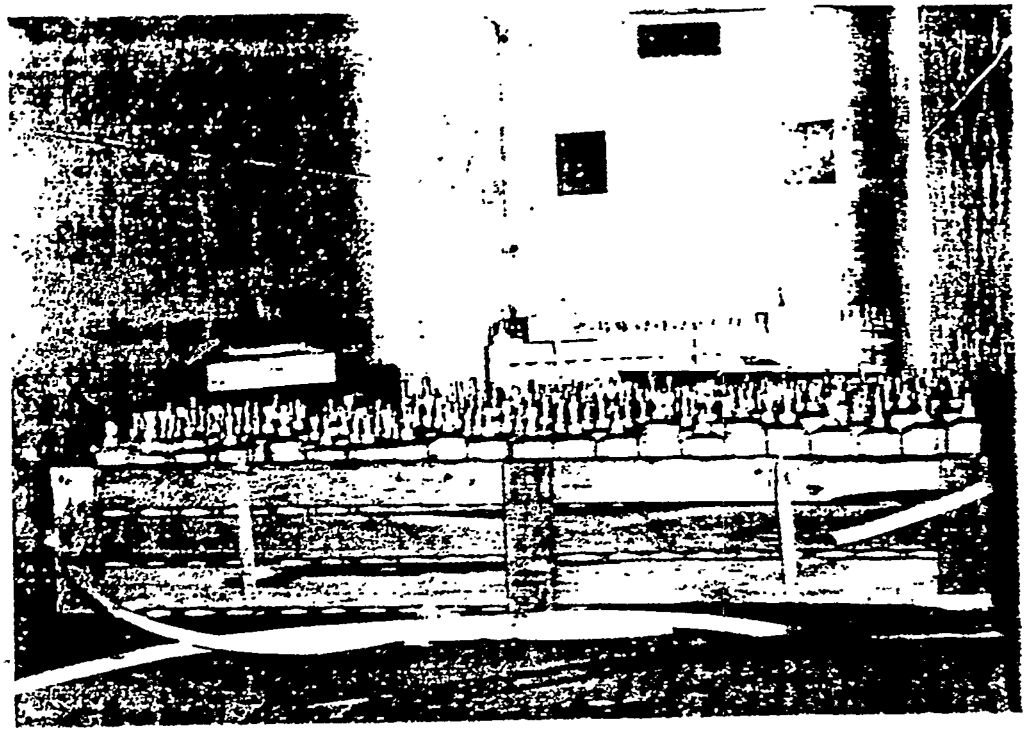
Table 2. Standardized mortality ratios for selected causes of death in monitored and nonmonitored white male Y-12 workers[a]

Causes of death	Never monitored		Monitored	
	SMR[b]	Obs[c]	SMR	Obs
All deaths	0.90 (0.81, 0.99)[d]	405	0.93 (0.79, 1.08)	164
All cancer	1.03 (0.82, 1.27)	84	0.98 (0.67, 1.37)	33
Liver cancer	1.23 (0.14, 4.43)	2	1.59 (0.02, 8.83)	1
Lung cancer	1.12 (0.74, 1.62)	28	1.46 (0.83, 2.37)	16
Kidney cancer	0.46 (0.01, 2:56)	1	3.27 (0.66, 9.55)	3
Brain and central nervous system cancer	2.18 (0.94, 4.30)	8	0.69 (0.01, 3.83)	1
All diseases of the nervous system sense organs	0.66 (0.13, 1.93)	3	0.00 (1.67)[e]	0
Vascular lesions of the central nervous system	0.84 (0.50, 1.31)	19	0.80 (0.32, 1.64)	7
Respiratory diseases	0.85 (0.50, 1.34)	18	0.46 (0.12, 1.19)	4
Chronic nephritis	0.64 (0.07, 2.30)	2	0.00 (1.09)[e]	0

[a]U.S. white male death rates adjusted for age and calendar year were used as the standard.
[b]Standardized mortality ratio.
[c]Observed number of deaths.
[d]95% Confidence interval.
[e]Expected number of deaths where observed deaths is zero.

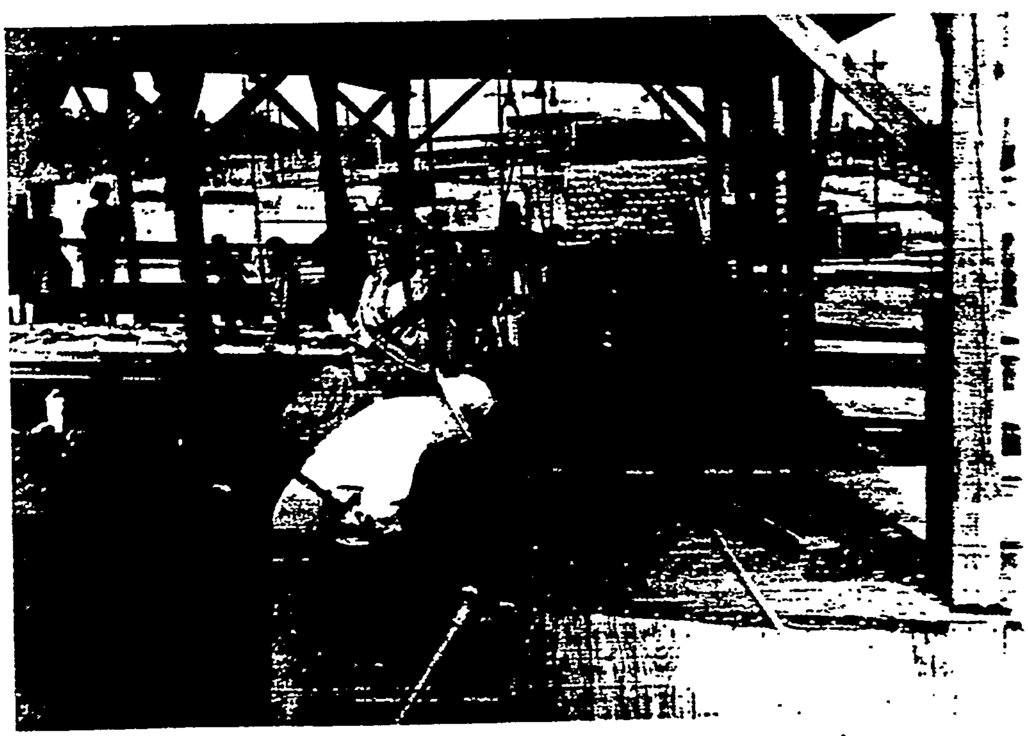
where it has been seen are, among others, neurological (e.g., tremors) and psychological (e.g., memory loss) and gingivitis. These signs are hard to distinguish from some natural aging effects that, of course, are another feature of this group. Consequently, the first step in getting the current study started has been to locate foremost experts available in mercury toxicology and chronic mercurialism diagnosis and to get their recommendations on what tests and procedures should be used (rather than to simply repeat what was done in the 1974 study). Eight experts are now serving as a panel to develop the protocol and study plan to be conducted by an outside medical group. It is hoped that the planning can be completed and that examinations can begin in the next few months. ■

ORO/PH-55-762-7



Mercury flasks arriving in a tractor trailer at the Rust Engineering unloading facility.

ORO/PH-55-762-4



Mercury flasks being unloaded by Rust Engineering personnel.

Mercury Material Balance

In addition to the concern for worker health, another area of interest for this task force in 1983 was to develop the best estimates possible for the amount of mercury lost or unaccounted for from the lithium cascade operations. The figure most often reported in the media in recent months has been 2.4 million lb—usually referred to as "spilled" or "lost" mercury. That number comes from the Y-12 1977 report, *Mercury Inventory at Y-12 Plant, 1950 Through 1977*. In this report, the number is correctly referred to as being the amount of mercury lost plus that not accounted for. The distinction between the amount lost and the amount not accounted for has at times been blurred, but, in fact, most of the losses are pretty well known. The amount discharged to the air or into the creek is indeed lost from our control but it can be accounted for.

The task force approach has been first to bring the 1977 data on the amount of mercury that can be accounted for up to date. Millions of pounds of mercury were removed from the process equipment and flasked since January 1977. The other accounted-for numbers were reviewed and revised as appropriate. A major effort was expended on reviewing the best remaining records of mercury transfers into Y-12 and on restudying the receiving operation. The mercury-receiving operation was carried out by Rust Engineering for AEC, and all their records, which were transferred to the Records Depository in Atlanta, were destroyed as scheduled some years ago. Rust did not weigh the mercury as received from the General Services Administration (GSA). Some original GSA flasks are shown in Figure 15. A pipeline led underground to the Colex cascades, and accountability for the mercury became the responsibility of Y-12 at the valve in that receiving line.

Then the losses presented in the 1977 report were reevaluated based on the history of the period, interviews, and other reports. A number of losses not previously recognized were identified and added to the list. While some errors were found and some new information

ORO-65-782-2

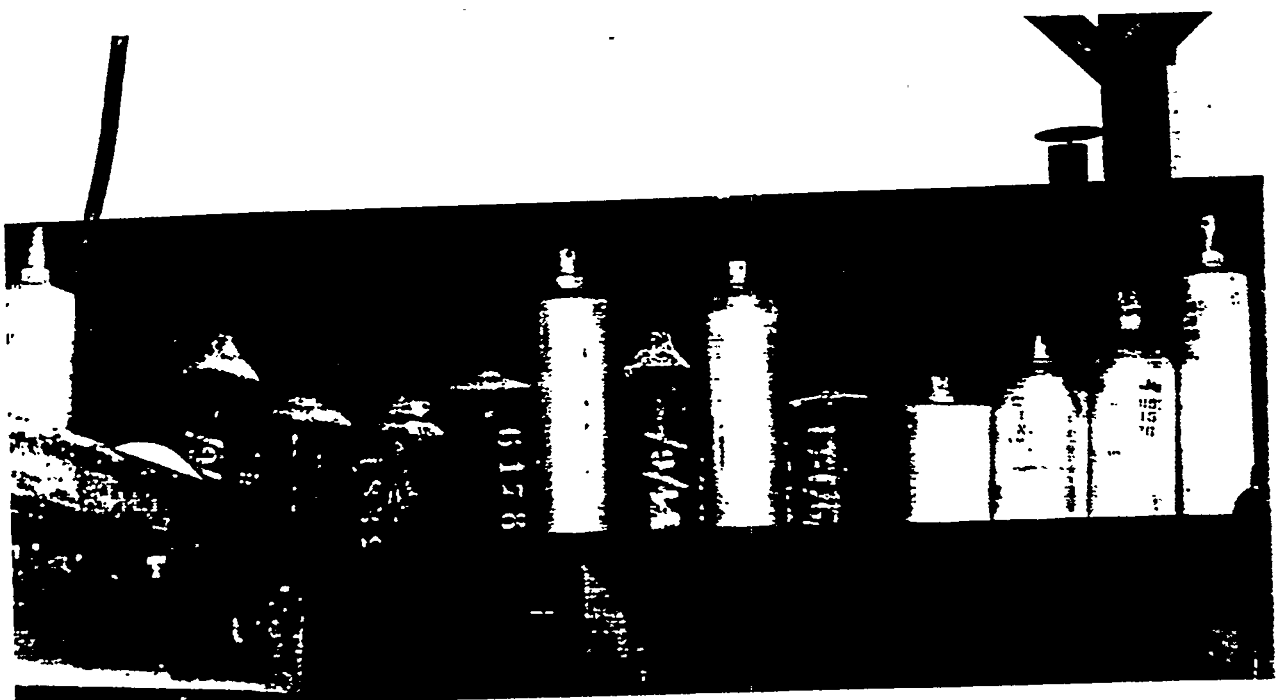


Figure 15. Variety of original flasks received from GSA in 1955 (nominal contents, 76 lb of mercury).

turned up, the net differences between the 1977 and 1983 figures are not major ones, and they do not alter the picture drastically (Table 3). Given the time allotted for the preparation of the 1977 report, namely, two weeks, and the effort expended (two people working part-time), the accuracy of the 1977 estimate is commendable.

The 2.0 million lb lost or not accounted for is lower than the 1977 figure (2.4 million lb) not because of a change in the estimated receipts but because of net increases in several of the accounted-for categories. The great majority of the accounted-for material is that quantity of mercury actually put into flasks and weighed, and this number is very well known. The other numbers are the best estimates that can be established from records and inspections.

The 0.7 million lb in known losses includes losses to the air, water, and land. The losses to air and land are much higher than estimated in our 1977 report (494,000 vs 87,000 lb), and the losses to the water (creek) are lower (239,000 vs 470,000 lb). The rationale for each of the new estimates was developed in detail by the task force, and it is the consensus of this task force that these are better estimates than the 1977

Table 3. Y-12 mercury material balance

	Best estimate, UCC-ND mercury task force, June 20, 1983	Best estimate, Y-12 Report, June 9, 1977
Vouchered to Y-12	*a*	*a*
Accounted for		
Returned unopened or rebottled and stored/sold	*a*	*a*
In lithium hydroxide tails, sold and stored	*a*	*a*
In Building 9201-5 scrap, sold	14,000	10,000
In Building 9201-5 sludge, sold to Mallory	174,000	111,000
As flasking overage given to GSA	*a*	*a*
In Building 9201-4 equipment, still in place	200,000	*a*
In sludges and sumps, Alpha-4	250,000	100,000
In Building 9201-2 sewer pipe, at ORNL	800	*b*
Accounted-for total	*a*	*a*
Lost or not accounted for	2,025,056	2,437,752
Lost to air	51,300	30,000
Lost to East Fork Poplar Creek	238,944	470,000
Lost to New Hope Pond sediment, Chestnut Ridge	6,629	7,200
Lost to New Hope Pond sediments now in place	8,475	*b*
Lost to ground, Building 9201-5 spill accident	49,853	49,853
Lost to ground, seven other spills	375,000	*b*
Lost to ground, Building 81-10 operations	3,000	*b*
Lost total	733,201	557,053
Not-accounted-for total	1,291,855[c]	1,880,699[c]

[a]These data are classified for security reasons.

[b]Data not available in 1977 report.

[c]The numbers are certainly not accurate to ±1 lb. Such specific totals are listed for accounting purposes only.

numbers. The details of these environmental losses are discussed later in this report.

The 1.3 million lb not accounted for is then arrived at by difference. The task force identified several probable explanations of where about half this mercury (645,000 lb) may be located (see Table 4). Two of these explanations do deserve mention here; however, they are not understood well enough for the mercury to be included in the known-losses or accounted-for categories. One is an estimate of 60,000 lb, a very rough guess at what might be contained within the production building structures (walls, ceilings, floors, insulation, etc.). Since there is no analytical sampling basis for such an estimate, the approach used was to follow the pattern of an Environmental Protection Agency (EPA) study of the chlor-alkali industry, which showed substantial losses of mercury each year by this route in those kinds of plants.

Another explanation for an even larger part of the not-accounted-for mercury is the big uncertainty as to the amount of mercury actually received at Y-12. An intensive study of the available records of mercury procurement was carried out during June 1983. Persons who had worked in the Colex process were interviewed, and GSA offices in Washington, D.C., were visited to try to get information on which to base a better mercury material balance. But no hard data on the actual amounts shipped or received could be located. It has been speculated that the difference between the quantity of mercury Y-12 was charged with and the quantity actually received might have been about 500,000 lb, perhaps half of the 1.3 million lb not accounted for. One former AEC official interviewed guessed the shortage might be as high as the equivalent of 900,000 lb. Obviously, there is no way the exact figure can be determined at this time. The

Table 4. Results of 1983 task force study

	Mercury (lb)	
	June 1983	June 1977
Mercury lost, spilled, dumped to environment		
Lost to air (1950–1963)	51,000	30,000
Lost to East Fork Poplar Creek (1950–1982)	239,000	470,000
Lost to ground under Y-12	428,000	50,000
Lost to sediments in New Hope Pond	15,000	7,000
Total	733,000	560,000
Mercury not accounted for	1,300,000	1,900,000[b]
Speculations[a]		
Did not receive	500,000	
In building structures	60,000	
Other specific losses	85,000	

[a]These estimates cannot now be proven.

[b]The number most often reported in the news media is 2.4 million lb, and this is either referred to as mercury lost, dumped, spilled, or unaccounted for. The correct terminology is lost and not accounted for since it was a sum of these two categories in our original Y-12 report.

figure on which our not-accounted-for number is based is the quantity charged to Y-12. the total of a number of transfer vouchers that AEC sent to Y-12 and declared to be the basis for Y-12 accountability. No actual weighing took place, either by GSA, Rust Engineering, or Y-12. GSA furnished the mercury from the government's strategic material stockpile, Rust Engineering received and dumped the mercury into the pipeline, and Y-12 filled the cascades from the pipeline. Each of the tens of thousands of flasks was assumed to contain 76.0 lb of mercury, the internationally accepted convention. But it is known from interviews with people involved in the original dumping operation that many flasks leaked, that some were only partially filled, and that some were even empty.

Even before the Colex process was shut down, Y-12 started to return some of the excess mercury to the stockpile. One of the first shipments in 1957 involved thousands of flasks that had been procured to serve as an operating reserve but had never needed to be opened. In making arrangements for this shipment, the GSA instructed the AEC to ask Y-12 to ". . . ship only full units. Sort out obvious leakers or unfilled units . . ." In addition, Y-12 filled a number of requests from other customers at AEC's instructions. However, because of the large number of complaints received about leaky flasks and shortages, Y-12 finally refused to ship any more until the mercury was reflasked. This information suggests that a number of the original flasks shipped to Y-12 were not in good condition and that not all the flasks contained 76 lb of mercury. The correspondence between the AEC and the Y-12 Plant subsequent to this period reveals an increasing concern with the poor condition of the flasks, which culminated in the GSA decision to authorize AEC and Y-12 to procure new flasks and to rebottle the inventories on hand at Y-12 in these flasks. As a result, thousands of the old flasks in poor condition were sold as scrap many years ago, and the inventory now maintained at Y-12 as part of the government's stockpile is carefully warehoused and kept in excellent condition (Figure 16).

Of the 1.3 million lb of mercury officially not accounted for at this time (including 0.5 million lb for shortage in receipts), pretty good guesses can

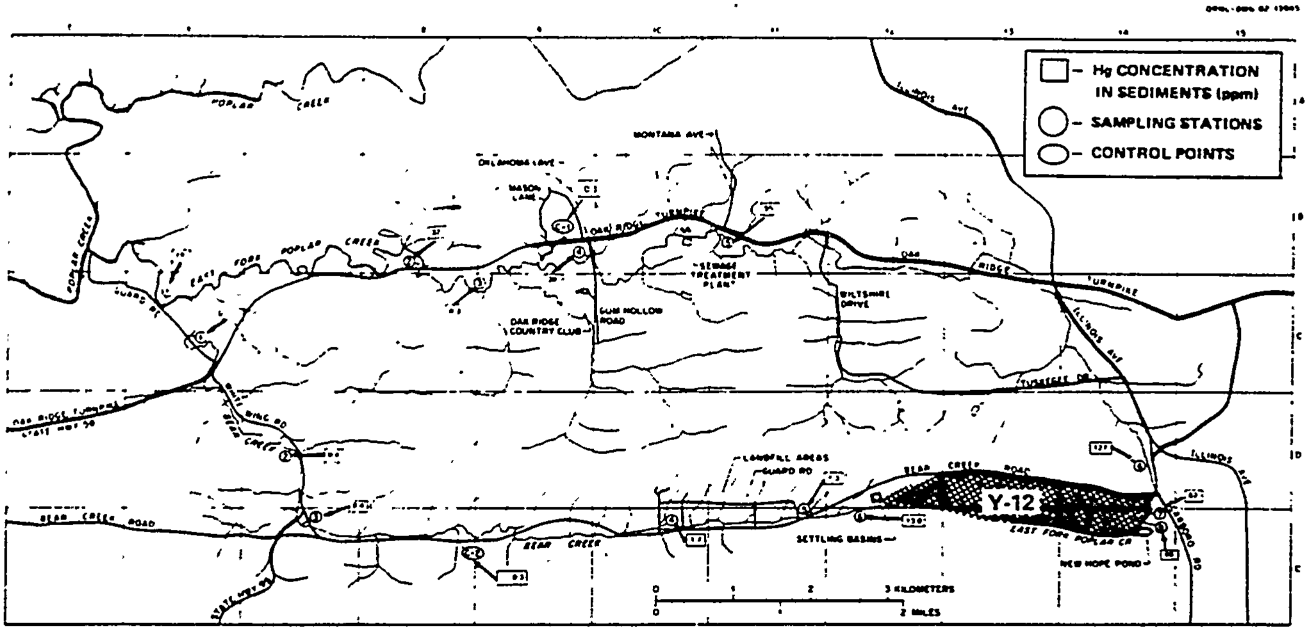
Y/PH 214321

Figure 16. Mercury stored for GSA in the mercury warehouse (Building 9720-26).

be made as to the whereabouts of 0.645 million lb. That is to say that the task force's estimate of the true amount not accounted for is the balance, or about 650,000 lb. This is about 30% of the Y-12 mercury consumption.

The task force noted with interest this statement in a 1975 EPA report on mercury accountability in the chlor-alkali industry: "We have made estimates to cover all known or suspected losses so that the amount of mercury introduced is accounted for. Actually, such accounting is not possible in a typical mercury cell chlor-alkali plant. Instead, for the industry as a whole, only about 50% of its annual mercury consumption can be accounted for. This does not imply that mercury is indiscriminately lost to the environment; rather it is most difficult to estimate where mercury may accumulate in the system and to what extent."* ■

*D. Garrett, *Material Balance and Technology Assessment of Mercury and Its Compounds*. EPA Report 560/3-75-007, prepared for Environmental Protection Agency, Office of Toxic Waste, 1975.



The Y-12 Plant area at the lower right is located in Bear Creek Valley and is bounded by Pine Ridge to the north and Chestnut Ridge to the south. It is drained by two streams, both rising in the Y-12 Plant area. East Fork Poplar Creek flows in an eastward direction away from the plant into New Hope Pond. It then flows north from New Hope Pond, west through the city of Oak Ridge, and west through an unpopulated area to join Poplar Creek near the Oak Ridge Gaseous Diffusion Plant. Bear Creek flows west from Y-12 through uninhabited woods to its confluence with East Fork Poplar Creek. The sampling data shown were reported September 7, 1982, in an ORNL study by Van Winkle et al.

Environment

The losses of mercury to the Y-12 environment as currently (1983) estimated can be summarized as follows:

Lost to	Amount (lb)
Air	51,000
Water	239,000
Land	443,000
	733,000

Losses to air. Most of these losses occurred during Colex process operations (38,000 lb) because of mercury that got into the ambient air during maintenance operations and because of the continuous seepage of mercury from pumps and other equipment. The process required the pumping of hundreds of millions of pounds of mercury under pressure each day. In addition to the Colex losses to the building air and through the ventilation systems, the Elex process operations lost 8300 lb through venting of mercury along with hydrogen gas produced in the process prior to its shutdown in 1957. Smelting of Elex scrap from Building 9204-4 discharged another 5000 lb into the atmosphere. The Elex (electrical exchange) process predated Colex by several years: development started in 1950 and production was started in 1953 in Building 9204-4 and stopped in 1956. The process was less efficient than Colex and was therefore replaced.

Losses to water. Losses to East Fork Poplar Creek are largely traceable to a process waste stream. The operation responsible for generating this waste was an essential step to the process, but this operation was modified in 1958 to reduce mercury losses. Before 1961, about 200,000 lb of mercury was discharged to the creek from the Colex waste stream as a very dilute, neutralized acid waste. The waste stream carrying this mercury into the creek appeared almost clear because of the low concentrations involved. Simulated solutions made up in the laboratory from neutralized mercuric nitrate appear clear and water-white, as would be expected since the solubility of mercuric oxide is 50 ppm and the concentrations discharged were less than this.

In 1963 and 1964, New Hope Pond (Figure 17) was built to permit mixing so that the degree of variation of the pH of the effluent from the Y-12 Plant could be reduced. The pond was also intended to provide a contingency capacity for control of accidental spills of oils or other substances. An unanticipated benefit was the retention of substantial quantities of mercury-containing sediment. These sediments, as well as the continuing discharge of mercury since then, came from secondary sources of mercury, not from the aforementioned process waste stream that was improved in 1958 and finally discontinued in 1963. Secondary sources of mercury contamination are building drain systems, sewers, and lines connecting to the creek headwaters or upper East Fork Poplar Creek. These lines contain mercury in some of the joints as well as contaminated sludges that continue to serve as a source of small amounts of mercury. Another 29,000 lb is estimated to have been lost to the creek from 1950 to 1983 from all sources other than the Colex process waste stream described earlier. The discharges to the creek are summarized in Figure 18 and Table 5. To arrive at an estimate of the total discharge to East Fork Poplar Creek, several other possible sources of loss had to be considered. Table 5 shows three other source estimates added to the measured values from Figure 18.

This estimate of 239,000 lb was derived largely from measured, historical data reported in Y-12 quarterly reports and can be contrasted to the 470,000-lb estimate in the 1977 report mentioned earlier. The current figure is largely made up of the Colex waste stream measurement, 199,500 lb, plus the 19,500 lb measured since 1961, the sum of which is 219,000 lb. In the 1977 report, the comparable estimate was 235,000 lb. At that time, it was erroneously concluded that the analytical procedures used over the years measured only the soluble mercury, and since it was well known that insoluble mercury was also present in the plant discharge, the 235,000-lb estimate was

Y/PH 15864

Figure 17. New Hope Pond facing north toward the gap through Pine Ridge through which East Fork Poplar Creek flows to Oak Ridge from the pond exit in the background. The Y-12 Plant is located to the left up the valley. The pond influent is distributed by a header all along the foreground shore of the pond.

Y-DWG 83-1586

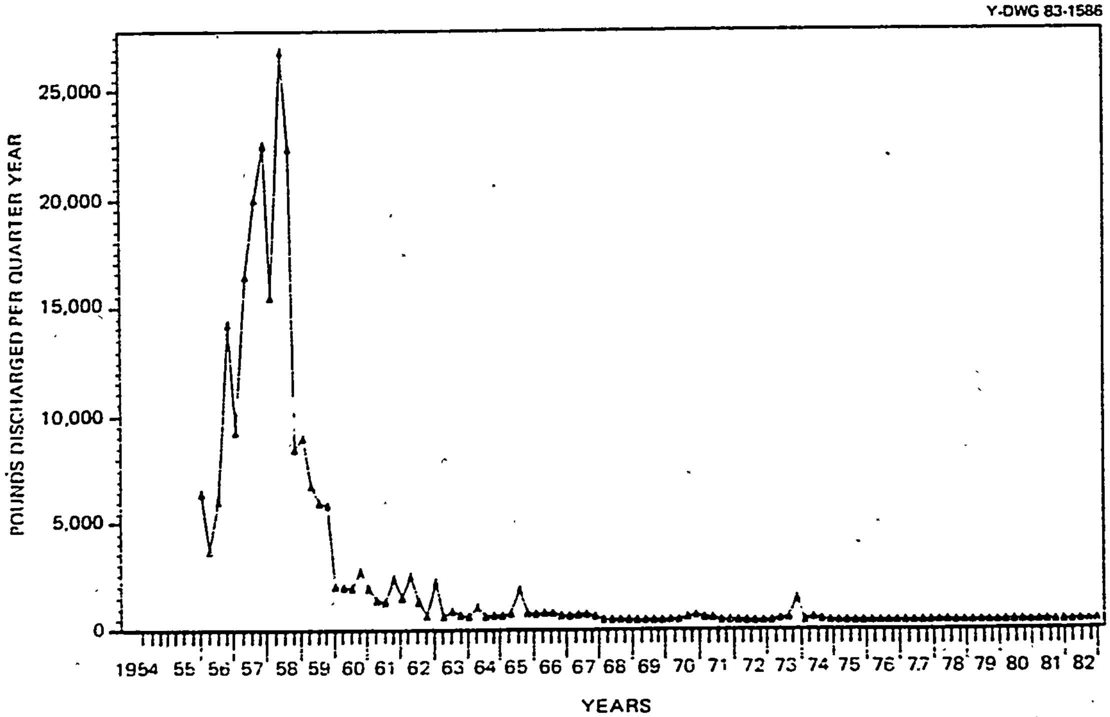


Figure 18. Mercury concentrations measured each quarter in East Fork Poplar Creek multiplied by the measured stream flows. The sum of these quantities is 219,000 lb.

Table 5. Losses (discharges) to East Fork Poplar Creek

Losses	Mercury (lb)
Orex, Elex, Colex, 1950–1954 (estimated)	11,000
Colex waste stream, 1955–1960 (measured)	199,500
Colex metallic and bottom sludges, 1955–1964 (estimated)	7,500
Since 1961 (measured)	19,500
Storm flow adjustment (estimated)	1,500
Total	239,000

doubled. There were possibly two facts that understandably misled the authors of the 1977 report and caused them to come to this conclusion. At the time the report was prepared, water samples from the creek were being filtered and only soluble mercury was being measured. This practice was, however, only begun in January 1974, and prior to that time, the analyses produced numbers which included all the mercury in the sample, soluble plus insoluble. No explanation can now be found as to why the procedure was changed in January to start filtering, but in June 1977 (the month the report was published), the practice was stopped. Another fact that may have been a source of further confusion is that the analytical procedure used from 1957 to 1959, when most of the mercury was discharged, called for filtration of all samples as a first step. However, the filtration was performed through a filter paper impregnated with cadmium sulfide and thus provided a means for removing all mercury, soluble and insoluble, from the sample to ensure measuring the total amount in the filter in subsequent steps. The bottom line is that it is now felt that the doubling of the 235,000 lb was not justified; doubling the estimated quantity discharged during the 3½-year period from January 1974 to June 1977 (311 lb) could be justified, but this does not appreciably affect the total estimate of 239,000 lb. It is the collective judgment of the task force, including those who actually developed the 1977 numbers, that 239,000 lb represents a sound and better estimate than 470,000 lb.

Now a more serious question about these losses arises from the concern over the adequacy of the sampling methods used throughout the years, not over the analyses themselves. There are two aspects of concern. It is now known that mercury deposits on the walls of sample containers and that water samples should be acidified to preserve the initial concentrations. But a greater concern is whether quantities of mercury might have been discharged as either metallic mercury or in sludges containing adsorbed or metallic mercury that were very heavy and stayed on the bottom of the creek, thus not being picked up by the water samples taken from the surface or upper portion of the stream. An estimate of 7500 lb from this source was included in the 239,000-lb figure, but it cannot now be documented.

Lake sediment studies. To provide some verification of both the chronology and quantity of estimated mercury losses to the creek, the task force has undertaken a limited sediment sampling program in Watts Bar and Chickamauga lakes. It has been estimated that 8000 lb is contained in the floodplain and sediments of East Fork Poplar Creek.* The remainder (230,000 lb) presumably is in sediments in Poplar Creek, the Clinch River, or in the remainder of Watts Bar and in the river system below. The initial form of the majority (80%) of the 239,000 lb was soluble or a very finely divided suspension of mercuric oxide, so it could well have been transported considerable distances. Mercury is adsorbed onto the fine particles of silt in the water and would settle very slowly and be resuspended readily. This is contrary to the notion sometimes suggested or implied that since mercury is so dense, it will settle out readily. Experience with mercury contamination from chlor-alkali plants shows that mercury can be transported considerable distances (hundreds of miles) downstream.

Sediment cores were collected at six locations, four on Watts Bar and two on Chickamauga (Figure 19). The cores consist of cylindrical

*Assuming 40 ppm, 12 in. deep, 20 ft wide, 20 miles long, and 100 lb/ft^3 density.

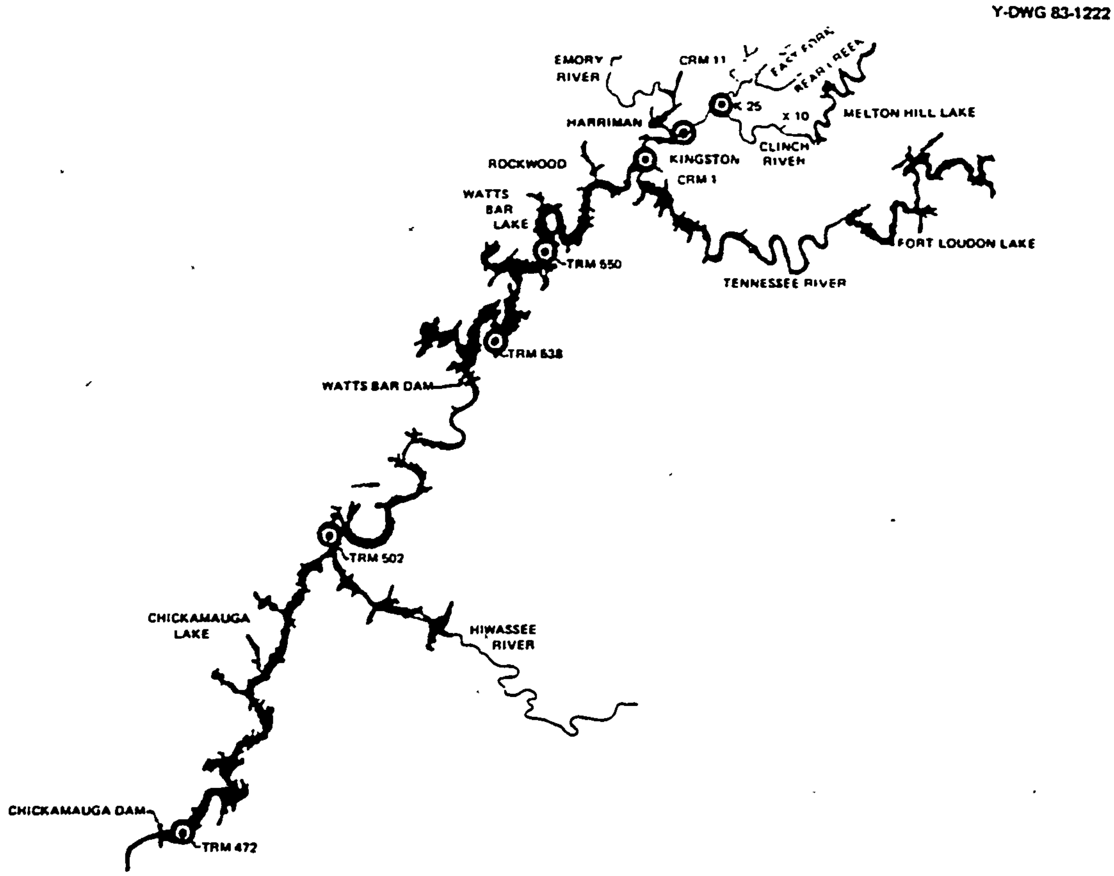


Figure 19. Lake coring study sample sites—Watts Bar and Chickamauga.

columns (or plugs) of mud obtained by pressing a length of open pipe vertically through the entire thickness of lake sediment. The sediment is then extruded from the pipe and sliced into sections (or layers) representing progressively older deposits as the bottom of the core is approached. Each layer is then analyzed for mercury. In addition to the cores obtained recently, one core, collected in 1977 on the Clinch River near the Oak Ridge Gaseous Diffusion Plant (ORGDP), was also retrieved from frozen storage and partially analyzed for mercury. Sediment coring sites were selected by staff of the Earth Sciences Section of the Oak Ridge National Laboratory (ORNL) Environmental Sciences Division, who also conducted the coring operation.

Table 6 and Figure 20 give the results of the task force's sediment study. All but one core showed a sharp peak in mercury concentration in layers 14 to 39 in. below the present sediment surface in the lakes. These subsurface peak concentrations vary from 3.5 to 180 ppm of mercury, with the highest peaks occurring at locations closest to Y-12. Most of the cores penetrated into sediment layers with only natural background concentrations of mercury (about 0.2 ppm), which indicates that these layers probably were deposited before 1955. It has been possible to date sediment layers by using known radioisotope release dating methods or by simple calculations based on how long the reservoirs have been filled and collecting sediments (40 years for Watts Bar; 43 years for Chickamauga). Both techniques showed that peak concentrations in the Watts Bar sediments correspond to silts laid down from 1955 to 1960, about the time of peak discharges from Colex operations to East Fork Poplar Creek. The correspondence is quite good, suggesting that there was little or no delay in transport to the lake from Y-12.

Table 6. Results of sediment core analyses for mercury—Watts Bar and Chickamauga lakes

	Mud covering[a] (in.)	Highest concentration (ppm)	Core penetrated to background	Recent concentrations (ppm)
Watts Bar Lake				
CRM[b] 11.0		180[c]	No[c]	
CRM[d] 6.8	32	13.2	Yes	3.8
CRM 1 (Kingston)	39	46.0	No	3.0
Thief Neck (TRM[e] 550)	36	14.0	Yes	1.0
Gillespie Bend (TRM 538)	14	7.0	Yes	0.5
Chickamauga Lake				
Hiwassee River (TRM 502)	30	0.5	No	0.35
Chickamauga Dam (TRM 472)	14	3.5	Yes	0.7

[a]Depth of mud covering to level of highest mercury concentration.

[b]CRM = Clinch River Mile.

[c]This core was taken as part of an ORNL study conducted in 1977. At the time of the study, this core was preserved and was analyzed for mercury during September 1983.

[d]This core was added to the study after the graphs in Figure 20 were prepared.

[e]TRM = Tennessee River Mile.

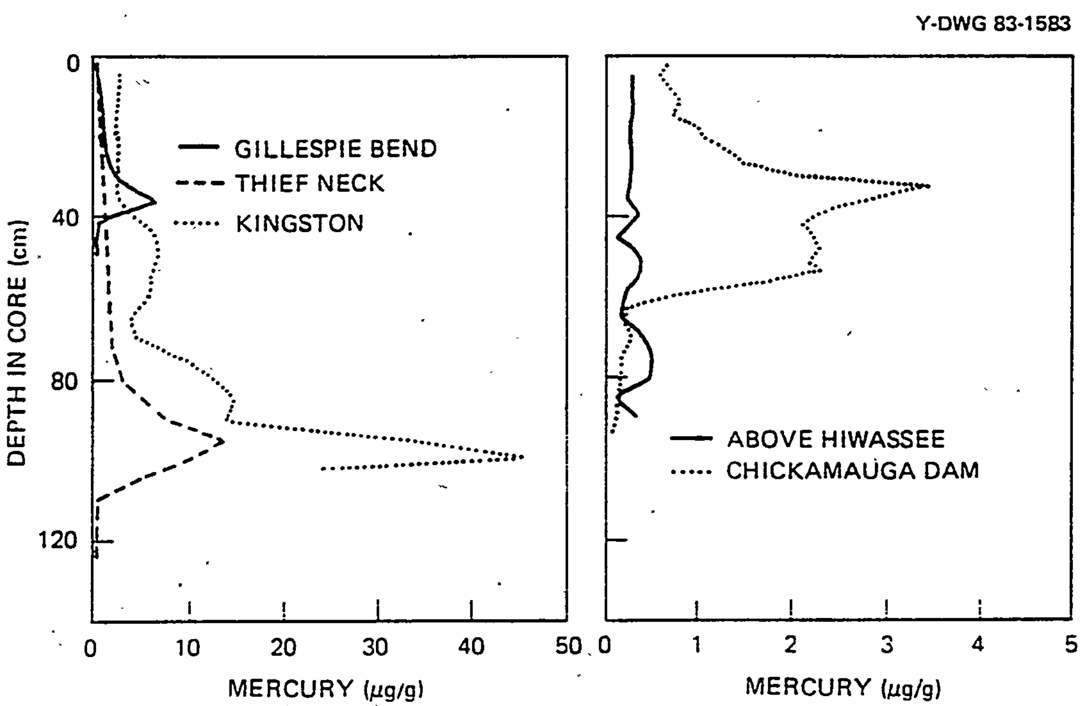


Figure 20. Sediment core analyses for mercury; cores taken from Watts Bar and Chickamauga lakes.

The core taken in Chickamauga Lake just above the confluence with the Hiwassee River did not reveal a subsurface peak in mercury, all values being low (0.2 to 0.5 ppm) and close to natural background values. One interpretation of the data for this core is that Watts Bar trapped essentially all the mercury released at Y-12. The coring site is about 20 miles below Watts Bar Dam and above the influence of mercury discharges (since 1963) from a chlor-alkali plant located on the Hiwassee River. The core collected here contained numerous sandy layers (indicating high water-current speeds and possibility of disturbance) and may not truly represent continuous undisturbed accumulation. In addition, this core may not have penetrated into layers deposited between 1955 and 1960 when mercury losses from Y-12 were highest.

The second core from Chickamauga Lake did show a subsurface peak in mercury and did penetrate into layers with natural background concentrations of mercury (Table 6). Interpretation of the vertical distribution of mercury in this core is complicated by the presence of two upstream sources of mercury—Y-12 and the chlor-alkali plant (operating since 1963) on the Hiwassee River. Preliminary evaluation of the data for this core suggests that the sharp increase in mercury that begins at about 25 in. below the surface can be traced to the chlor-alkali plant. The profile also reveals that the substantial reductions in mercury discharges from the chlor-alkali plant accomplished in the 1970s have been reflected in decreasing concentrations in lake sediments. Further work is expected to resolve the contribution of each facility to the mercury in Chickamauga Lake sediments.

It is of interest, of course, to speculate on how much mercury is in Watts Bar Lake. Calculation requires estimates of average concentrations, average mud thicknesses, and densities. Estimates made on the basis of so few samples relative to the large acreage involved are extremely imprecise, but they suggest that numbers of several hundred thousand pounds are easily within credible range, given the data we now have. And, as stated earlier, the peak layers of mercury are covered with 1 to 3 feet of sediments deposited in later years.

Bear Creek. The task force also investigated the possibility of mercury contamination of Bear Creek, which rises at the west end of the Y-12 Plant and flows west down Bear Creek Valley. The topography of the plant area is such that drainage from the mercury processing areas involved in lithium separation would not affect Bear Creek. Sampling has shown no mercury in the waters of the creek nor in groundwater monitoring wells downgradient of the S-3 ponds. However, one sample did show contamination (13 ppm) of sediments close to the headwaters in the vicinity of the S-3 ponds. Sampling of groundwater from excavations nearby have shown the presence of mercury [100 parts per billion (ppb)] in water believed to have been contaminated by seepage from the S-3 ponds. The source of mercury which in the past may have been and which now may be contaminating Bear Creek is a processing operation in which small quantities (1 lb per month) of mercury are used as a catalyst (from 1950 to the present). This operation has nothing to do with the lithium cascade operations described in this report. Much effort is now being concentrated on shutting down S-3 pond operations to eliminate this contamination problem. Downstream sediment mercury in Bear Creek is at background levels at about 2 miles above the creek's confluence with East Fork Poplar Creek.

Losses to land. Losses of mercury to the land from Y-12 Plant operations are summarized in the following:

	Amount (lb)
Accidental process losses (eight spills)	425,000
New Hope Pond sediment (current estimate)	8,500
Chestnut Ridge (New Hope Pond sediment)	6,600
Lost to ground at Building 81-10	3,000
Total	443,100

Information on this facet of the task force's study was developed largely from discussions with employees. Each of these spills involved loss of mercury to the ground. Recovering metallic mercury spilled on the ground is very difficult, even when the ground is dug up and recovery is attempted by roasting; this method was used in some cases. None of the many small spillages and leakages during plant operations and maintenance are included in the 443,100-lb total referred to here because almost all the mercury from these was recovered; it was not lost to the environment. The data on spills (Table 7), 425,000 lb for eight incidents, can be contrasted with the five spills described in the 1977 report. In addition to those five, included now are three other accidents identified in this 1983 study that should properly be defined as process accidents or spills in which mercury was lost to the ground. These three incidents all occurred in Building 9201-2; the total loss was 95,000 lb. Figure 21 shows the location at the plant site of the eight spills.

The New Hope Pond sediment data were estimated from core samples analyzed for mercury. In 1973, about ten years after the pond was constructed, sediment levels had built up so that dredging became necessary. The pond was dredged, and the sediment was removed to the top of Chestnut Ridge just to the south of the pond. The estimated mercury content of the removed sludge is 6600 lb.

Building 81-10 was a shed containing a roasting furnace for recovery of mercury from sludges, wastes, dirt, and other similar materials. During those operations, some mercury was spilled on the concrete pad and on the ground. Core samples taken some years ago were used to develop the estimate given here (3000 lb).

Environmental concern during Colex operations from 1955 to 1963 was focused on quantities of mercury lost to the creek because it was an expensive process material; mercury concentrations were measured and reported quarterly beginning in 1954. Stream flows, and thus total quantities of mercury, were measured and reported beginning in the last quarter of 1955. Mercury releases were primarily an economic rather than an environmental concern because mercury was then thought to be relatively harmless and nontoxic except in the vapor form. The possibility that mercury releases might constitute a much more serious problem was first publicized in the news media in March 1970 by a Canadian scientist who linked high concentrations of mercury in fish in Lake St. Clair to biological conversion of inorganic mercury to highly poisonous methylmercury. The

Table 7. Process accidents involving mercury at the Y-12 Plant, 1951–1966

Date	Location (Building)	Estimated quantity spilled (lb)	Estimated unrecovered loss (lb)	Comment
1951–1955 (3 accidents)	9102-2	100,000–120,000	95,000	Losses in pilot plant
Jan. 1, 1956	9201-5	113,000–170,000	70,000	Coupling broke on pump
July 17, 1956	Ramp north of 9201-5	22,500–90,000	85,000	Valving error
Summer 1956	Between 9204-4 and 9201-5	22,500–90,000	85,000	Valving error
Nov. 15, 1956	9201-5	22,500–45,000	40,000	Column plugged
Mar. 28, 1966	9201-5	105,000	49,853	"Sight glass" tubing broke on tank
Total			424,853	

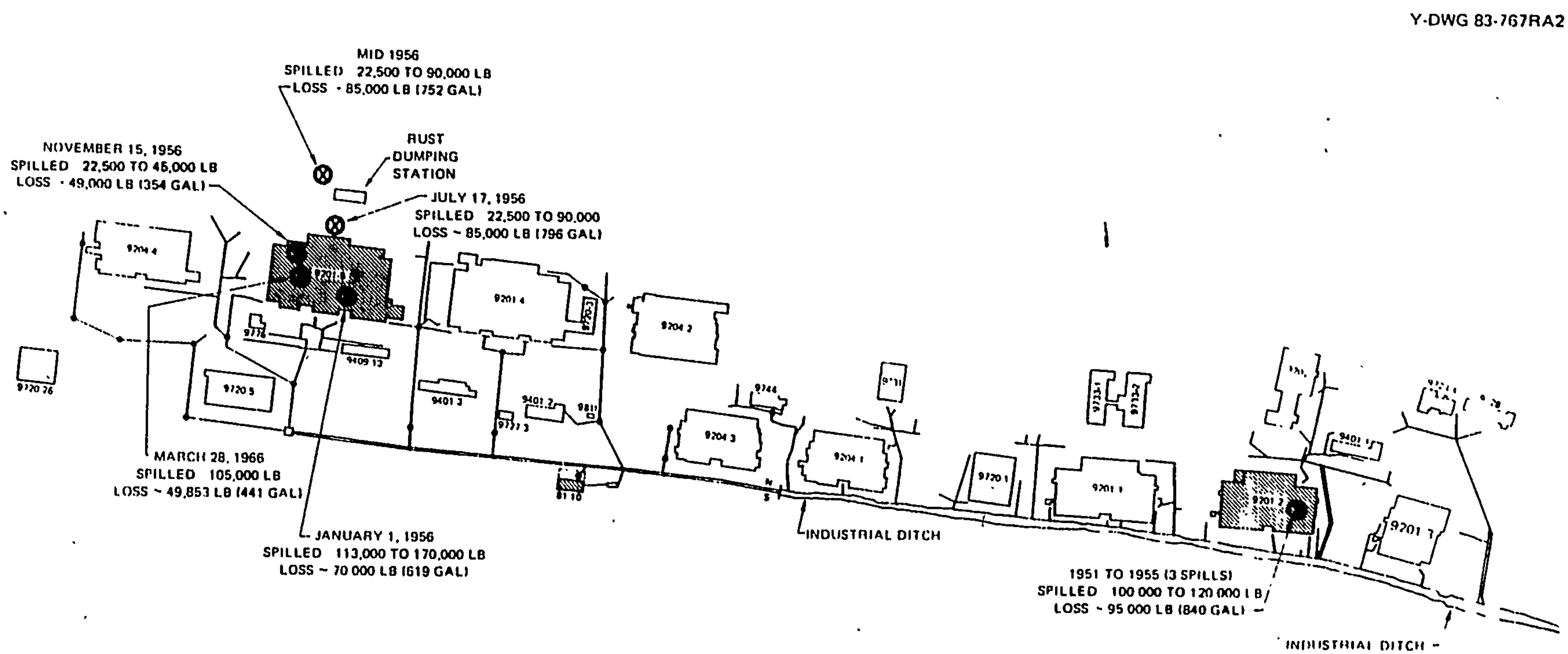


Figure 21. Location of accidental mercury losses to the ground at the Y-12 Plant.

attention thus focused on the methylmercury problem in 1970 was responsible for initiating widespread studies of mercury concentrations in fish as well as in sediments, river water, and other possible sources of contamination throughout the United States. The first Y-12 study of mercury concentrations in East Fork Poplar Creek fish was done in 1970, and it showed a range of 0.32 to 1.30 ppm. A comprehensive ORNL review in that same year surveyed fish from all over the United States and showed, for comparison, mercury concentrations in fish from Pickwick Lake, which ranged up to 2.1 ppm, and from the Holston River, in which the concentrations ranged up to 4.4 ppm.

Several environmental studies have been conducted since 1970. The mercury studies done since the 1970 study by Merwyn Sanders of Y-12 include a study made in 1974 by an AEC–Oak Ridge Operations (ORO) employee, John Reece, who studied sediments in East Fork Poplar Creek and Bear Creek. In 1976 and 1977, J. W. Elwood of ORNL studied water, fish, and sediment from Poplar Creek and the Clinch River. Sampling of mosses and liverworts by ORNL's S. Gough was done in 1981, followed by W. Van Winkle's study in 1982 (ORNL), which examined fish and sediments in East Fork Poplar Creek. Ann Stiff of ORGDP studied fish from Poplar Creek in 1982. These environmental studies have been described in some detail in testimony by Chester R. Richmond and Stanley I. Auerbach at the July 11, 1983, congressional hearings. Their testimony is included as Appendix A of this report.

Fish data. Data on fish generally have been consistent in showing some higher than recommended [Food and Drug Administration (FDA): 1.0 ppm] levels in East Fork Poplar Creek fish but lower levels in those from Poplar Creek and the Clinch River. Statistical analyses of the fish data for 1976 versus 1982 show no basis for believing that mercury concentrations are either decreasing or increasing at the junction of Poplar Creek and the Clinch River or at the junction of East Fork Poplar Creek and Poplar Creek itself. Although there are a few fish in each year's sampling that exceed 1 ppm, the averages are the controlling factor and they are well below the FDA guideline. See Figures 22 and 23 for graphic depictions of mercury concentrations in several species of fish from these local waters.

Sediments. In 1970 Merwyn Sanders (of the Y-12 Plant) found a maximum of 63 ppm mercury in 10 sediment samples. In 1974 John Reece (AEC-ORO) found a maximum of 72 ppm and an average of 19 ppm in 16 samples. Van Winkle (ORNL) found a maximum of 127 ppm in his 1982 study. One sample from the property on Illinois Avenue at the Oak Ridge Turnpike ran 480 ppm. Looking at these maximums may suggest that sediment contamination in East Fork Poplar Creek has been growing worse in recent years. But examination of all the numbers suggests no sound basis for either confirming or denying this idea. Two factors complicate the analysis: (1) concentrations vary with distance from Y-12 so that location of sampling is important and (2) concentrations vary with particle size of the sediment, the amount of sand or of silt. Uncertainties exist in the early data on both counts. There is one set of fairly homogeneous samples taken at K-25 for the annual environmental reports over the past six years. These involve sediment samples taken each year at the same 14 locations in Poplar Creek below the junction of East Fork. Statistical analysis of these data showed no evidence of a real change in sediment contamination over this past six-year period.

Putting all of these environmental mercury data in proper perspective is difficult from a technical standpoint. Survey and review articles on mercury in the environment over the years present instances of fish, water, and sediment samples having even higher concentrations in other locations in the United States. The situation with East Fork Poplar Creek is somewhat unusual in that most other mercury discharges have been to much larger streams or to rivers. However,

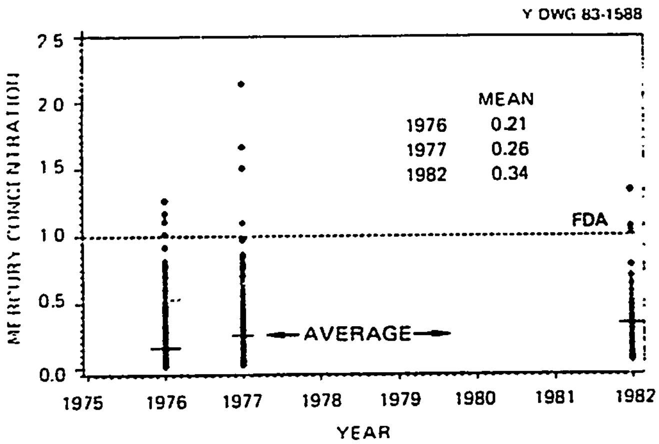


Figure 22. Fish from Poplar Creek and the Clinch River. Species sampled include bass, bluegill, catfish, and crappie [concentration measured in micrograms per gram (ppm)]. The dotted line represents the Food and Drug Administration (FDA) guideline for edible fish flesh.

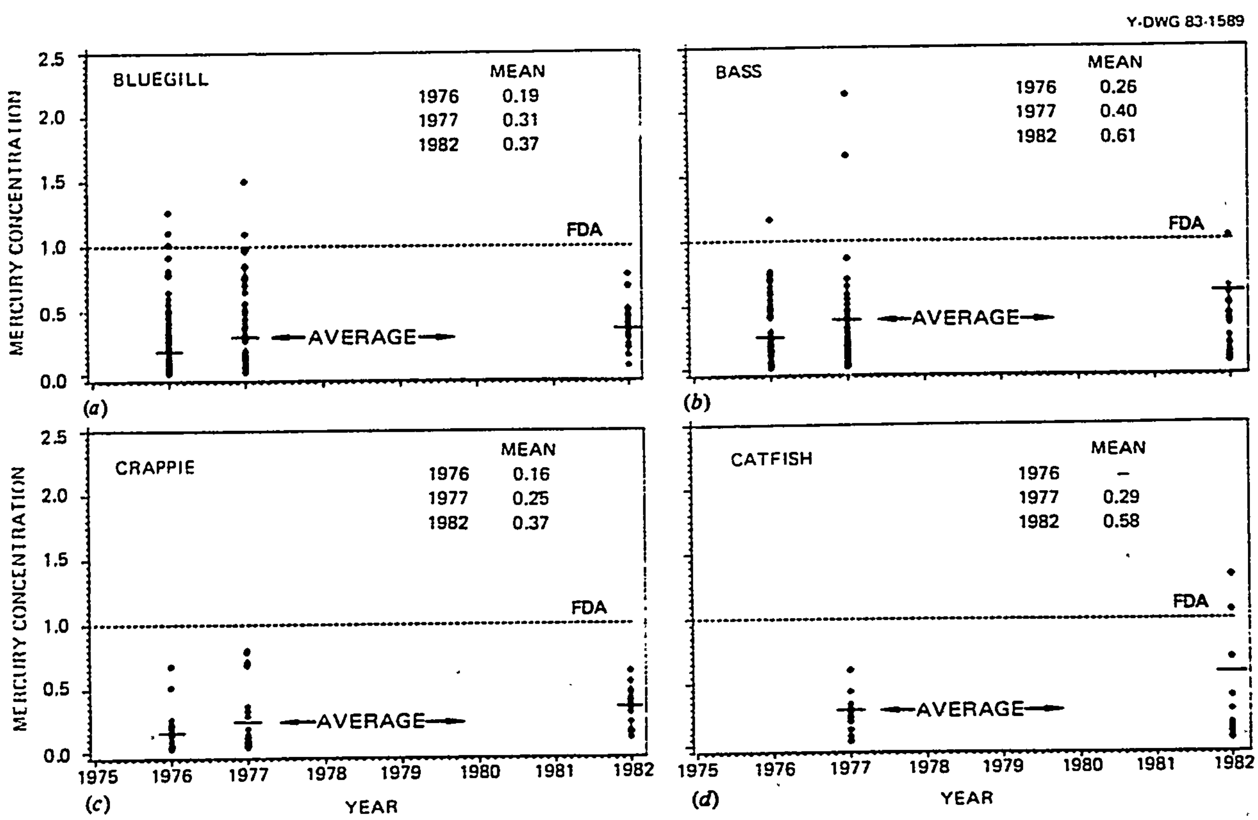
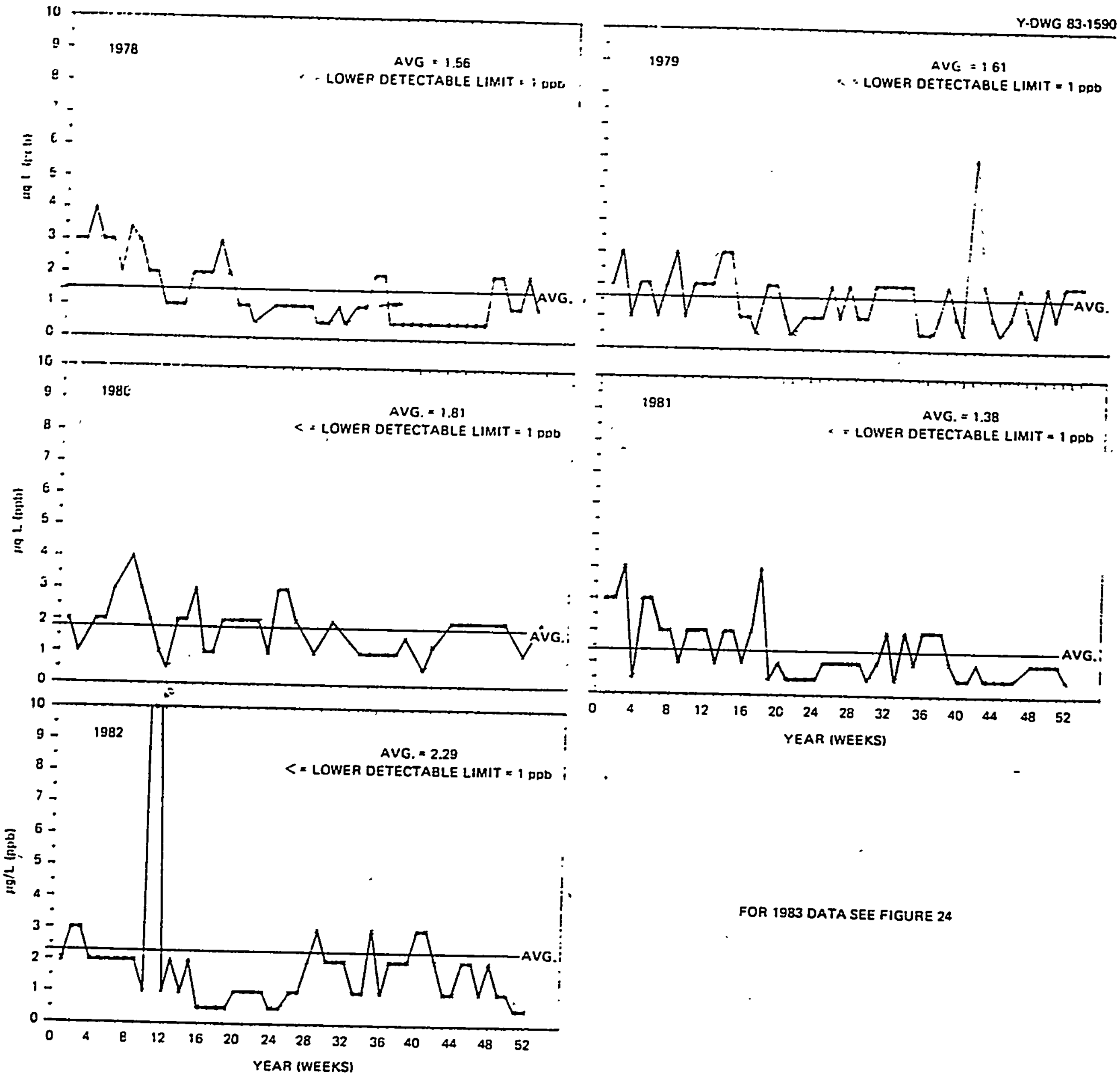


Figure 23. Fish from Poplar Creek and the Clinch River. Species sampled: (a) bluegill, (b) all bass, (c) crappie, and (d) all catfish [concentration measured in micrograms per gram (ppm)]. The data are from studies by J. Elwood, ORNL, 1976 and 1977, and by A. Stiff, K-25, 1982.

the relevant question is, what health risk problems, if any, do past or current discharges pose today? The risks from East Fork Poplar Creek water and sediment contamination are so low that they are very hard to quantify. In this study, the only target population thought to be in any way at risk is persons who would continuously eat large amounts of East Fork Poplar Creek fish, which in some cases concentrate mercury to levels higher than the 1.0 ppm recommended by the FDA. However, the small fish population makes it unlikely, though not impossible, for a person to take in dangerous quantities of methylmercury. This topic is addressed more fully in the testimony by C. R. Richmond and S. I. Auerbach (see Appendix A). ■



Mercury concentration in water at the New Hope Pond outlet, 1978–1983.

Current Assessment

Current discharges to East Fork Poplar Creek are monitored by taking samples of the outflow of New Hope Pond (Figure 24). "Grab" samples are taken every Monday morning (and almost daily since mid-1983), and a "composite" sample is taken on a flow-proportional basis throughout the week. During 1983 the average daily concentration of mercury in the outflow from New Hope Pond has been 2.6 ppb. The actual grab sample data are shown in Figure 24. The large increase in mercury discharges occurring in June and July resulted from a cleanup program undertaken in the Colex production area that unavoidably stirred up old sediments and increased the amount of mercury discharged to the creek. In addition, a water line break in Building 9201-4 in July resulted in an added discharge of residual mercury.

Discharge data (grab samples) for recent years are shown in the figure opposite, with average concentrations shown for each year. Large increases (spikes) other than those observed during the summer of 1983 are associated with large storm runoffs at the time the samples were taken (Monday mornings). These data are also represented (in less detail) in Figure 18.

Since grab sampling started several years ago, the average daily concentration has been 2.0 ppb.* Taking flows into account, the average quantity is about 60 g (2.1 oz) per day, or about 50 lb per year for this period.

This average concentration, coincidentally, is identical to the standard established by EPA for drinking water (2.0 ppb), but it is in excess of the guideline for water quality established by the state of Tennessee for fish and wildlife streams (0.05 ppb). That guideline is considerably lower than the EPA level of 2.0 ppb and below the

*In the years since the 1970 publication of biological methylation of mercury, a number of reviews have been published that report on the distribution of mercury in the environment, both naturally occurring and man-caused, in rivers, sediments, soils, rain water, vegetables, and many others. These reviews verify that our local concentrations are significantly above usual natural background though less than some natural sources. A worldwide review by Kaiser and Tolg in 1980, for example, cites among other values ranges of river water concentrations near naturally occurring mercury deposits of 0.5 to 100 ppb, in hot springs and mineral waters of 0.01 to 20 ppb, and in the Rhine (Wiesbaden) of 0.03 to 8.4 ppb. [G. Kaiser and Tolg, "Mercury," in *The Handbook of Environmental Chemistry*, Vol. 3, Part A, Springer-Verlag, New York, 1980.]

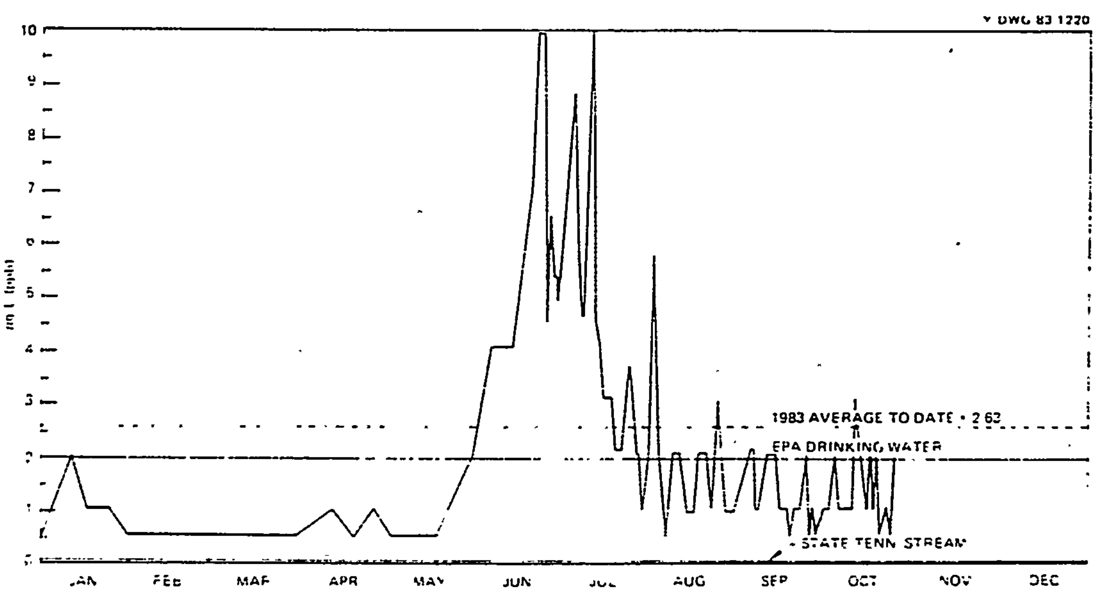


Figure 24. Mercury in New Hope Pond effluent—East Fork Poplar Creek.

state guideline for domestic water supplies (0.2 ppb) to allow for the natural process of concentration of mercury by fish (×10,000) so that it will result in fish flesh concentrations below the allowable FDA guideline of 1.0 ppm. A number of actions are under way to try to further reduce plant discharges.

Material balance studies have been done during the last year to find out where this mercury originates. Pipes feeding water into the creek headwaters that flow into New Hope Pond were sampled and the flow was measured. Effluent pipes from Buildings 9204-4 and 9201-5 together contributed about 47%, pipes from Building 9201-4 contributed about 44%, and pipes from Building 9201-2 contributed about 8% of the mercury entering New Hope Pond during a careful two-day study in December 1982. Figure 25 gives plant locations and results of sampling from these effluent lines at that time. The pond effluent on those days was 42 g, and about 100 g (71%) was retained in the New Hope Pond basin.

In the last few months, there has been an active program to identify and clean up the secondary mercury sources in the Building 81-10 mercury recovery area; the sumps of Buildings 9201-4, 9201-5, and 9201-2; drain lines; and storm sewers. In addition, there have been two water-line breaks this past summer that have spilled a lot of water into the basement of the Colex process building (Building 9201-4); the first break resulted in an increase in mercury discharges to the creek. The second of these breaks has been contained in the building basement and mercury is being separated from the water to reduce its concentration to a value acceptable to the state prior to discharge to the creek.

In addition, Y-12 is undertaking subsurface studies to determine whether mercury accumulations can be detected below sites of major spills or operating buildings. A further objective is to find out whether there is any significant contamination of groundwater from these past losses. Three wells at each of ten locations have already been drilled and are being cased to permit groundwater samples to be taken. Analyses of the cores taken from these holes show very little mercury in the soil around the old production buildings. But these sites were chosen to monitor groundwater downstream of spill locations and were not drilled at the exact sites of the known spills. Full results will not be available from this program for several more months. Also under study is the Chestnut Ridge site, which was used for storage of sediment dredged from New Hope Pond in 1972, to see whether it is contaminating groundwater. In addition, many other analytical and engineering studies are under way in support of the DOE–EPA–State Memorandum of Understanding on Y-12. ■

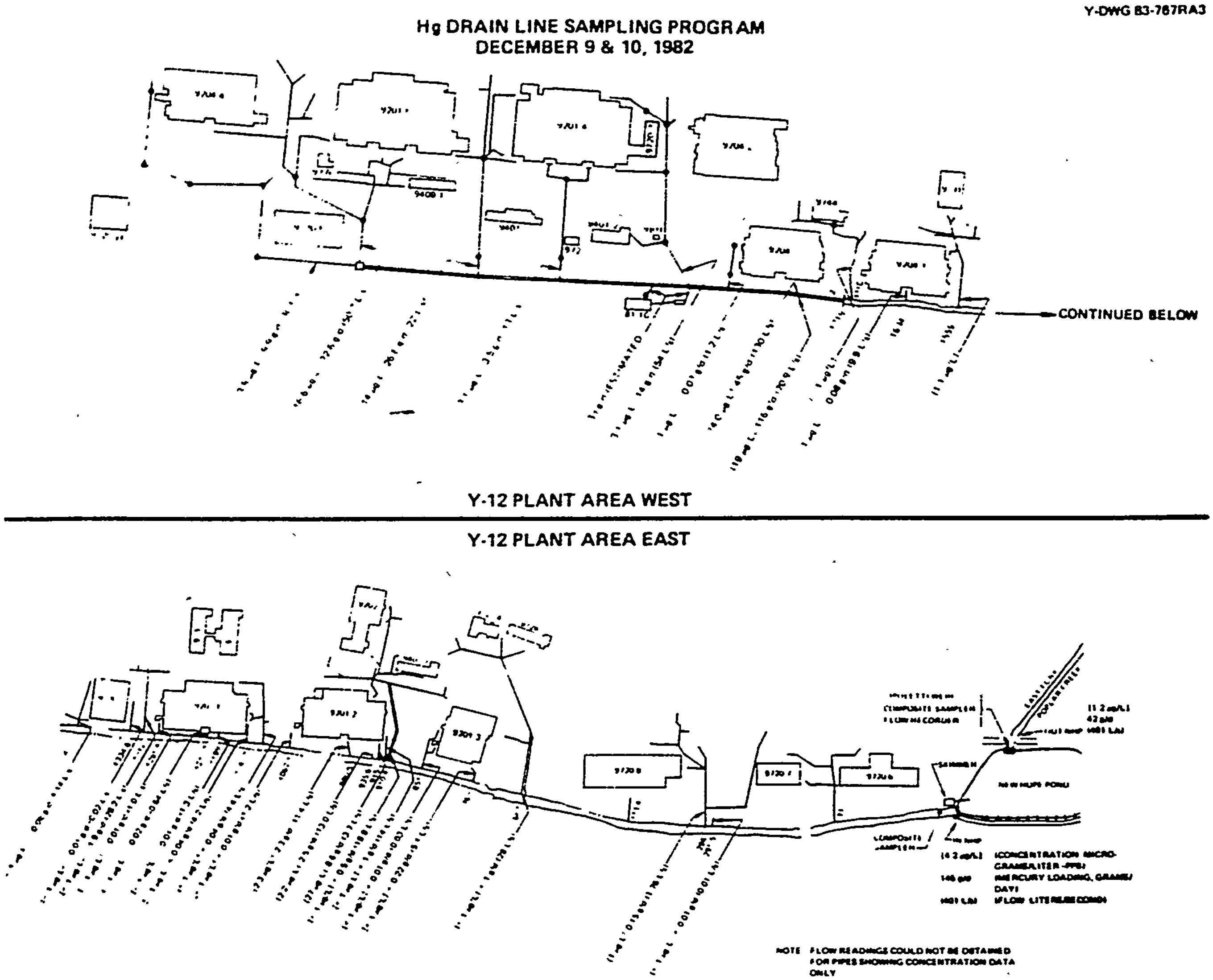


Figure 25. Sampling locations and results from the December 9–10, 1982, check of Y-12 Plant drain lines for mercury content.

Conclusions

Worker health was clearly a major concern of both the AEC and Y-12 Plant managers during the period of Colex operations from 1955 to 1963. During the start-up period in 1955, much higher concentrations of mercury vapor in the workplace air were experienced than were desired and a major effort was required to reduce these concentrations to acceptable levels. This effort was successful early in 1956, and operational levels for the next seven years were acceptable. No effects of chronic mercurialism were found in a 1974 follow-up study of those workers who had shown the highest mercury urinalysis values. A 1983 epidemiological study by ORAU found no significant differences among Y-12 mercury workers, Y-12 nonmercury workers, and a U.S. general population group in the death rates from all causes or from a number of different kinds of cancer. There is no evidence here at Y-12 or in other studies of mercury exposure that would suggest that mercury causes cancer. Another medical checkup of the mercury workers at higher risk is currently under way.

Material accountability has been restudied in an effort to develop the best estimate of the mercury material balance. There are a number of increases and decreases from the 1977 Y-12 report, and these differences have been reconciled. The combined "lost" and "unaccounted-for" mercury total is 2.0 million lb rather than 2.4 million lb. Of the 2.0 million lb, 0.7 million lb was lost to air, water, and land, leaving 1.3 million lb that is unaccounted for using the 1977 accounting system. Although it cannot be documented, it is the task force's opinion that a sizable part (0.5 million lb) of this unaccounted-for mercury was never received by Y-12, and good guesses can be made as to the disposition of another 0.15 million lb, which leaves a net unaccounted-for estimate of 0.65 million lb.

Environmental concerns in the Colex operations were focused on the quantity of mercury discharged, and these releases were monitored beginning in 1954. The quantities released and their origins have been detailed in the present studies. The sources and nature of most of the discharge to East Fork Poplar Creek are known. The majority of the mercury was discharged in a very dilute process waste stream (not as metallic mercury) between 1956 and 1959. In 1958 changes were made in the process to reduce these losses significantly. The quantities released in recent years are of course far smaller, in the past six years an average of 2 ppb or about 15 lb per quarter compared with some 2000 lb per quarter in 1960. Studies using drilling techniques to try to determine whether groundwater is contaminated and possibly to learn something about the current location of mercury lost to the ground in Colex accidential spills are in progress.

Available data support the judgment that there is no immediate or foreseeable risk to the health of the public as a result of past or current mercury discharges other than an unlikely possibility of harm that would result if a person were to ingest on a continuing basis a large number of East Fork Poplar Creek fish containing higher than 1 ppm mercury. At the Y-12 Plant the programs under way and being planned should further reduce the present mercury discharges into the creek and so reduce the likelihood of problems arising from this source. ■

Appendix A

Congressional Testimony by C. R. Richmond and
S. I. Auerbach, Union Carbide Corporation,
on the Impact of Mercury Releases
at the Oak Ridge Complex

TESTIMONY AT A JOINT HEARING
OF
THE SUBCOMMITTEE ON ENERGY RESEARCH AND PRODUCTION
AND
THE SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHT
OF THE
U. S. HOUSE SCIENCE AND TECHNOLOGY COMMITTEE
ON
THE IMPACT OF MERCURY RELEASES AT THE OAK RIDGE COMPLEX

SUMMARY OF ACTIONS AND ACTIVITIES RELATED TO MERCURY RELEASES IN THE OAK RIDGE AREA FROM DOE/UCC-ND OPERATED FACILITIES

C. R. Richmond
S. I. Auerbach

AMERICAN MUSEUM OF SCIENCE AND ENERGY
OAK RIDGE, TENNESSEE

July 11, 1983

A. REVIEW OF THE USE OF MERCURY AT Y-12

The first buildings of the Y-12 Plant were constructed along East Fork Poplar Creek in 1943 to carry out the first production-scale separation of uranium isotopes for the atomic bomb. Ten years later, in 1953, Y-12 was called upon to undertake the first production-scale separation of the isotopes of lithium for use in hydrogen bombs. Y-12's task at this time was made urgent by the USSR hydrogen bomb test in the fall of that same year. Like the World War II uranium efforts, the lithium process effort required a crash construction program and the overcoming of major technical difficulties. But these efforts also were a success, and the cascades were started up in 1955 after a remarkable 15-month construction period. They were stopped in 1963, having produced this essential strategic material needed for the national defense.

The process that made this challenging program a success is called "COLEX," the name being a contraction of "column-exchange." It is a chemical exchange process in which lithium isotopes are separated as they transfer between two chemical phases. One of these phases is an aqueous solution of lithium hydroxide and the other phase is a solution of lithium in mercury, a lithium amalgam. Many millions of pounds of mercury were essential to the project. Directives signed by President Eisenhower made the mercury available from the National Stockpile. It was this mercury used for the "COLEX" process from 1955 to 1963 that is the source of today's concerns and the subject of these hearings.

Concern for mercury toxicity was very much on the minds of both Atomic Energy Commission (AEC) and Y-12 managers and industrial hygienists as they prepared in 1953 and 1954 for "COLEX" operations. The process was to involve thousands of shift workers, and programs were instituted before the cascades went into operation to cope with the recognized hazards of breathing mercury vapor. The building floors were modified so that the floor drains emptied into special mercury collection tanks in the basement. Here mercury could be separated from mop water and other solutions before passing to other water-collecting sumps inside and then outside the buildings before going to the creek.

These precautions were taken because it was recognized that Y-12 was pioneering an entirely new process using pumps and other equipment that had never before been utilized for this particular application. The engineers anticipated frequent maintenance and troubles during start-up of these new processes involving pumping huge quantities of mercury under pressure. The first year of production, 1955, was indeed a troublesome one. Many problems developed with the equipment. Pumps and valves needed to be serviced often. The process equipment was full of mercury, and spillage of small quantities in maintenance operations was expected and encountered. It was accommodated by special drip pans, collection containers, and administrative procedures. The mercury concentration in the workplace air was monitored frequently. (In 1956, 280,000 air samples were measured.) In the 1955 cascade start-up, higher concentrations of mercury in workplace air were encountered than acceptable. Toward the end of 1955, for instance, many of the readings were in excess of the American Conference of Government Industrial Hygiene (ACGIH) recommended value of 0.1 mg/m^3. A urinalysis program had been started in 1953 and was expanded to provide a check on the worker mercury exposures. During the time that high concentrations of mercury in air were encountered in 1955, the urinalysis data also showed higher readings, although the averages for all workers never exceeded the recommended urinalysis mercury limit of 0.3 mg/L. Still, some individual workers had readings that did exceed the 0.3 mg/L level. When urinary mercury values for an individual remained at a high level for several specimens, the personnel (approximately 70 people) were assigned to other work areas, then returned when their urinalysis mercury levels dropped to the normal range.

In addition to the air sampling and urinalysis programs, there was a routine medical surveillance program with clinical examinations for all mercury workers every six months. Persons with a history of albuminuria, kidney problems, or hypertension were screened out and not allowed to work with mercury.

Toward the middle of 1955, AEC and Y-12 management recognized the urgency of reducing high mercury vapor levels, and a crash program was undertaken to bring the levels down. The program involved technical studies of substances that could reduce vapor pressure or that could dissolve tiny mercury droplets. Engineering changes to reduce process losses were involved, including a renovation of the buildings' ventilation systems with the installation of huge fans in the end walls to provide more fresh air to the buildings. Other changes included major new housekeeping programs and the installation of a special house-vacuum system for mercury pickup. The net effect of these and other administrative efforts is documented by the historical record of air concentrations, which shows that the air levels were dramatically reduced and under control by March 1956 and stayed under control during the next seven years of operation.

In 1974 a consultant from the National Institute for Occupational Safety and Health (NIOSH), Dr. Z. Bell, reviewed the Y-12 data on mercury worker exposure. He selected 50 of the original workers who had received high exposures (based on urinalysis) and asked the Y-12 medical staff to examine them according to a protocol that he furnished. None of the 23 employees still on the payroll showed any symptoms of mercury poisoning.

More recently, in 1983, Oak Ridge Associated Universities (ORAU) conducted a preliminary epidemiological study of the mortality of the Y-12 mercury worker population by comparing this group (1477) to the other Y-12 workers (4920), then comparing both groups to the U.S. population as a whole. The purpose was to determine whether there is any evidence to suggest that the death rates due to cancer or any other causes are higher for the employees who worked in the Y-12 mercury exposure areas than for other Y-12 employees. No such evidence was found. Death rates for mercury workers as a group were 93% of the rates for the U.S. population group to which they were compared, while the death rates for the other Y-12 nonmercury workers were 90% of the rates for the U.S. population. The statistical confidence intervals for each overlapped considerably, and no significant difference was found. Similarly, no difference was found between the Y-12 mercury workers and the other Y-12 workers in the death rates due to cancers, diseases of the central nervous system organs, respiratory diseases, or chronic nephritis.

Losses of mercury from the "COLEX" process at Y-12 between 1955 and 1963 can be classified as loss to air, water, and land. Losses to water (i.e., East Fork Poplar Creek) are for the most part traceable to a process waste stream. The operation responsible for generating this waste was a mercury purification step in the operation of the "COLEX" process but was successfully modified in 1958 and the modification significantly reduced mercury losses. Mercury was discharged to the creek from this source in the form of a dilute, neutralized acid waste. The appearance of this waste stream carrying mercury to the creek was that of an almost clear solution. The mercury was present as a soluble or as a very finely divided suspension of mercuric oxide.

In 1963 and 1964 New Hope Pond was built to permit mixing and thus to even out the varying pH in the effluent from the Y-12 Plant. An unanticipated secondary benefit was the retention of substantial quantities of mercury-containing sediment. The mercury in these sediments came from secondary sources of mercury, not from the "COLEX" process waste stream which was finally stopped in 1963. The secondary sources are contamination of building drain systems, sewers, and lines connecting the process buildings to the creek headwaters or ditch. These lines contain mercury in some of the joints and contaminated sludges, etc., which continue to serve as a source of small amounts of mercury.

During "COLEX" operations, concern was focused on quantities of mercury lost to the creek, with concentrations of mercury measured and reported quarterly starting in 1954. Stream flows and thus total quantities of mercury were measured and reported beginning in the last quarter of 1955.

The possibility that mercury releases might constitute a much more serious problem than posed by what was believed to be relatively nontoxic, inorganic mercury was first publicized in the news media in

March 1970 by a Canadian scientist, Norwald Fimreite, who had linked high concentrations of mercury in fish to biological conversion of inorganic mercury to methylmercury.

Significant incidents involving mercury contamination of people were those at Minamata (1953) and Niigata (1965) in Japan. Prior to the 1950s, mercury contamination often was related to the use of medicinals and usually cosmetics containing mercury compounds. However, I read recently that in 1700 a citizen of Fiwale, Italy, sought an injunction against a factory manufacturing mercuric chloride because of its lethal fumes.

Other incidents of mercury poisoning occurred between 1956 and 1972 involving thousands of people in Iraq, Pakistan, Guatemala, Yugoslavia, and Sweden. Often, these incidents were related to the ingestion of grain seeds treated with mercurial fungicides. In 1967, the Swedish Medical Board banned the sale of fish containing high concentrations of methylmercury from about 40 lakes and rivers.

In the early 1970s, restrictions on fishing and sale of fish were imposed in many areas of the USA and Canada, and both countries began to control releases of mercury-containing wastes into lakes and streams (Goldwater, 1971). By September 1970, an ORNL study showed 18 states where some restrictions were in effect. Prior to 1967, no one realized that inorganic mercury could be biologically converted to organic methylmercury.

It is important to realize that environmental and public health standards were not developed until the 1970s as shown in the Table 1. There were no metallic mercury standards prior to 1943. In the early 1970s (see Table 2), the value for mercury in air was decreased by a factor of two. No standard exists for urinary excretion. Y-12 has used the administrative guideline of 0.3 mg/L as a plant action value.

The attention that focused on the methylmercury problem in 1970 was responsible for initiating widespread studies of mercury concentrations in fish as well as sediments, river water, etc., throughout the United States. The first Y-12 study of mercury concentrations in East Fork Poplar Creek fish was done in 1970 and

Table 1. Environmental and public health standards and criteria for mercury

	Standard in 1950	Current standards and date effected		
		Units	(ppm)	Date
Air - Workplace (ACGIH)	0.1 mg/m^3 (1946)	mg/m^3	0.05 mg/m^3	1971
Water - Drinking (EPA)	None	mg/L	0.002	1975
Water - Stream (EPA)	None	mg/L	0.00005	1976
Effluent discharges (TN)	None	mg/L	0.05	1977
Fish flesh (FDA)[a]	None	µg/g	1.0	1979
Solid waste burial, EP Test (EPA)	None	mg/L	0.2	1980
Sediment	None	None	None	

[a]Not a formal regulation. An FDA administrative action level.

7

Table 2. Chronology of mercury standards

Year	Organization	Guideline/standard Air (mg/m^3)	Guideline/standard Urine (mg/L)
1943	American National Standards Institute (ANSI)	0.1	
1946	American Conference of Government Industrial Hygiene (ACGIH)	0.1	
1952	Y-12 Plant	0.1	0.3
1957	University of Rochester recommendations	0.1	0.3
1971	American National Standards Institute (ANSI)	0.1	
1971	American Conference of Government Industrial Hygiene (ACGIH)	0.05	
1972	American National Standards Institute (ANSI)	0.05	
1973	National Institute for Occupational Health (NIOSH)	0.05	
1973	Y-12 Plant	0.05	0.3

showed the range of 0.32 ppm to a high of 1.30 ppm (memorandum from Sanders to McLendon, dated August 1970, Appendix 4). An ORNL study in that same year surveyed fish from all over the United States and showed that mercury concentrations in fish from Pickwick Lake range to 2.1 ppm and in fish from the Holston River range to 4.4 ppm.

Current Assessment

The current situation on discharges to East Fork Poplar Creek is monitored by taking samples of the outflow of New Hope Pond. "Grab" samples are taken every Monday morning, and a "composite" sample is taken on a flow-proportional basis that represents the best estimate of the mercury discharged. Over the 24-month period from 1981 through 1982, the overall average concentration was 1.3 ppb versus the interim drinking water standard of 2.0 ppb set by the Environmental Protection Agency (EPA) in 1975. The maximum value was 7.0 ppb. Taking flows into account, this means that over these two years 64 lb of mercury was released, an average of 1.4 oz/day or 39 g/day. Almost all is suspended or insoluble mercury. Material balance studies have been done in the last year to find out where this mercury originates. Each pipe feeding water into the creek headwaters or the ditch that flows into New Hope Pond was sampled and its flow measured. The effluent pipes from Buildings 9204-4 and 9201-5 contributed 47%, the pipes from 9201-4 and 81-10 contributed 44%, and the pipes from 9201-2 contributed 8% of the mercury entering New Hope Pond during the two days studied in December 1982. Of the total amount entering New Hope Pond on those days, 100 g were retained in the pond and 42 g were released to the creek.

In the last few months there has been an active program to identify the sources and form of mercury contamination and to clean up the sources: the Building 81-10 salvage area; the sumps in Buildings 9201-4, 9201-5, and 9201-2; drain lines; and storm sewers. This cleanup activity has stirred up sediments in pipes and lines, which has resulted in creek concentrations that are temporarily higher than the levels of 1981-1982. It is expected that when these operations are complete the mercury levels in the creek will drop below the 1981-1982 levels.

In addition, Y-12 will undertake subsurface studies to determine whether mercury accumulations can be located below sites of spills or operational facilities. A further objective is to find out whether there is any significant contamination of groundwater from those past losses. Further studies under way include a study of the Chestnut Ridge sediment disposal site to see whether it is contaminating groundwater. In addition, a variety of specific efforts are under way in support of work being done by others: the University of Rochester, Battelle-Columbus, Department of Energy (DOE)-ORO, etc.

B. ESTIMATED HEALTH RISK TO PEOPLE AS A RESULT OF CONSUMING AQUATIC ORGANISMS FROM EAST FORK POPLAR CREEK

The ultimate question related to a mercury-contaminated environment is the risk to human health. We will attempt to estimate the degree of risk associated with consuming aquatic organisms from the East Fork Poplar Creek. To do this, one must estimate the level that mercury would reach in the tissues of man from consuming these organisms. It should be pointed out that mercury is ubiquitous. Everyone's tissues contain mercury and we are constantly taking mercury into our bodies through the daily consumption of food and liquids. There is information, although scarce, on the "normal" intake of mercury by people. Several studies suggest intakes of about 3 to 4 µg per day (see Gerstner and Huff, 1977). The U.S. Food and Drug Administration systematically samples and surveys market products. In 1973, the FDA survey indicated an average dietary intake of 2.89 µg of mercury per day. Most of this was from fish (Food Chemical News: August 4, 1975). Mercury concentrations in some fish and shellfish sometimes exceed 0.5 µg/g tissue.

The level of mercury that accumulates in human tissues depends on many factors, including the amount taken in and the biological half-life in man. The biological half-life is the time required for the mercury concentration in man to drop by one-half, providing no additional mercury is taken into the body. The biological half-life reported for methylmercury in man is 76±3 days (World Health Organization, 1976). Other data suggest an average biological half-life value of about 70 days, with a larger amount of variability from person to person. Thus, following a single intake, methylmercury would be absorbed from the gut and distributed to various body tissues. Half of the mercury would be lost from the body in about 70 days and only about 1.5% would remain after 420 days.

However, for repeated intakes, an equilibrium level is reached between intake to and loss from the body. For mercury, the equilibrium body level is about 100 times the daily intake. For small daily intakes the equilibrium level will be small, whereas larger equilibrium levels will result from larger daily intakes. In either case, the equilibrium level in the body, sometimes called the body burden, will be about 100 times the daily intake.

Methylmercury is the chemical form of mercury that is most toxic to man. The source of methylmercury in the environment may be inorganic mercury that has been methylated in water by bacteria. Usually from 80 to 95% of the total mercury in aquatic organisms is reported to be methylmercury. Fish incorporate the methylmercury into their tissues from the water. The methylmercury is relatively nontoxic to the fish because of their simpler nervous system as compared with humans. The biological half-life in fish is usually longer than that in man. For the purpose of this evaluation, we assumed that all of the mercury in fish and aquatic organisms from East Fork Poplar Creek is methylmercury. When fish or aquatic organisms are eaten by man, practically all of the methylmercury from these foods is absorbed from the gastrointestinal tract.

To estimate the concentration of mercury that will be reached in the tissues of humans, the amount of these organisms that is consumed and the frequency with which these organisms are consumed must be known. The consumption rate of fish and other aquatic organisms in the United States varies greatly. The average per capita consumption of fish in the United States was estimated to be in excess of 20 g/day (0.7 oz/day) or about 16 lb/year; however, 1% of the population may consume 77 g/day (2.7 oz/day) (Stroud, 1977).

From Swedish studies of Japanese individuals contaminated in the episode of Niigata and from biochemical studies in Finland and Sweden (Federal Register, 1979), it was concluded that the lowest blood level of mercury that would bring about signs and symptoms of methylmercury poisoning was 200 parts per billion (ppb) (0.2 ppm). The body burden would be approximately 30,000 μg (30 mg) of mercury. To obtain this equilibrium level requires a minimum daily intake of approximately 300 μg of methylmercury. In setting standards for large populations it is usual to apply a safety factor. The safety factor usually is 10.

Thus, the "allowable" level would be 20 ppb of methylmercury in blood or a body burden of 3000 μg (3 mg) of mercury. The corresponding intake required to reach this blood (or body) equilibrium level would be 30 μg of mercury every day.

The highest mean concentrations of mercury in aquatic organisms from the East Fork Poplar Creek were collected between New Hope Pond and the Bear Creek Road bridge at the entrance to the Y-12 Plant area. The mean concentration of total mercury from seven bluegill collected in this area was 2.13 μg/g fresh weight (Van Winkle et al., 1982). An individual would have to consume 14.1 g (0.5 oz) of these fish every day from this location before his blood mercury level would reach the "allowable" level of 20 ppb. It would take about one year for the body burden to essentially reach equilibrium. During that time, 11 lb would need to be ingested by that individual.

The mean concentration of mercury in the muscle tissue of frog legs and crayfish tails collected near this same station was 0.60 and 2.50 μg/g fresh weight, respectively (Blaylock et al., 1983). Thus, an individual consuming either 50 g/day (1.8 oz/day) of frog legs or 12 g/day (0.4 oz/day) of crayfish tails for about one year would accumulate the "allowable" body burden of mercury.

The mercury concentrations in fish tend to decrease with distance from Y-12. Therefore, larger quantities of fish would need to be ingested before the "allowable" body burden of mercury was reached. If, for example, the average concentration in fish was 0.2 μg Hg/g, an individual would have to consume 107 lb of these fish in one year to reach "allowable" body burden.

A sample of only one turtle was collected on the East Fork Poplar Creek some distance below where the other samples were collected. The concentration of mercury in the turtle was 0.46 μg/g fresh weight. Thus, an individual would have to consume 65.2 g/day (2.3 oz/day) of this turtle for about one year to reach the "allowable" body burden of mercury.

It should be remembered that the allowable level of 20 ppb of mercury in the blood has a safety factor of 10; therefore, a much larger quantity of the organisms could be consumed daily before reaching the "allowable" level in the body, a level at which the first symptoms of methylmercury poisoning may appear.

Another point that should be made is the size of the populations of aquatic organisms that inhabit the East Fork Poplar Creek. Fish populations in this stream have not been estimated using quantitative methods, but the populations do not appear to be very large. It is doubtful that a large number of organisms could be harvested on a regular basis from the East Fork Poplar Creek, especially the quantity required to provide food on a daily basis.

In summary, we feel that the release and subsequent widespread distribution of mercury in the Poplar Creek drainage basin and the Clinch River do not constitute an acute risk to human health or the environment. We cannot arrive at the same conclusion regarding the longer-term or chronic threat that the release might pose without more information on the locations and amounts of mercury in the aforementioned aquatic systems and on the extent of accumulation of mercury in human food chain organisms over extended periods of time.

C. ENVIRONMENTAL PROTECTION

The management of hazardous materials, their use, storage, surveillance, and disposal in a manner that ensures minimum impact on the environment is a line responsibility in each of the three Oak Ridge installations operated by the Nuclear Division. Each installation has in place an organizational unit to develop appropriate procedures and surveillance to ensure that the objective of the minimal environmental impact is achieved. At the Oak Ridge National Laboratory (ORNL) this unit is the Environmental Management Department of the Industrial Safety and Applied Health Physics Division. At the Oak Ridge Gaseous Diffusion Plant (ORGDP) and the Oak Ridge Y-12 Plant (Y-12), the environmental management departments are units of the Health, Safety, and Environmental Affairs divisions of the respective plant organizations.

At the Nuclear Division level, an office of Health, Safety, and Environmental Affairs, under the general direction of the ORNL Associate Director for Biomedical and Environmental Sciences, has the responsibility to initiate and/or coordinate installation environmental protection and monitoring programs consistent with the requirements of the Department of Energy (DOE) and to compile and issue annual reports of the monitoring programs. The organization charts in Appendix 1 provide more specific details.

The ORNL Environmental Sciences Division, a mission-oriented research and development unit of ORNL, has as its principal objectives (1) to conduct research leading to the development of pertinent environmental information about existing and emerging energy technologies, and (2) to utilize this knowledge in a way that is consistent with acceptable environmental protection concepts to prevent and solve problems arising during the development and implementation of these technologies. Within and without ORNL, the division's research provides and substantiates the environmental data, as well as the understanding of the environmental mechanisms, that are utilized by other organizations that have responsibility for evaluating or assessing health and safety impacts. The division's focus is on environmental matters, not human health or the related health science disciplines.

One example of this emphasis is the role the division has played, and continues to play, in studying mercury contamination on the Department of Energy (DOE) Oak Ridge Reservation and environs. While the Environmental Sciences Division has no direct authority to initiate environmental surveillance activities, it has been continuously responsive to requests to provide technical expertise on the mercury issue. As our testimony will indicate, the Environmental Sciences Division has recommended in reports and memoranda within the Nuclear Division/DOE organization that additional studies and monitoring are necessary to document the nature and extent of the mercury contamination problem in a scientifically credible and professionally responsible manner. Through our research on the DOE Oak Ridge Reservation, on the Holston River-Cherokee Reservoir in Virginia and Tennessee (Hildebrand et al., 1980a), and at the world's largest mercury mine in Almaden, Spain (Hildebrand et al., 1980b), the Environmental Sciences Division has developed an outstanding research group of geochemists, aquatic ecologists, and terrestrial ecologists publishing on various aspects of mercury contamination in the environment.

Mercury Studies Conducted by the Environmental Sciences Division at Oak Ridge National Laboratory

The purpose of the following discussion is to document that the Environmental Sciences Division at Oak Ridge National Laboratory has been involved in mercury studies for many years. Staff members of the Environmental Sciences Division were involved in mercury studies as early as 1970 (ORNL, 1971). The division has cooperated and jointly conducted research on mercury in the environment with federal agencies and authorities, state governments, and foreign countries. A large number of reports and open literature publications have resulted from these studies. A selected few will be used to document the division's involvement in mercury studies.

In the early studies funded under a research grant from the National Science Foundation, the investigators utilized the division's expertise in the cycling of radionuclides in the environment to conduct tracer studies with ^{203}Hg. The purpose of these investigations was to determine the cycling and concentration of mercury in the environment. For example, studies were conducted on: (1) the cycling of mercury in an old-field ecosystem to determine the uptake, concentration, and movement of mercury in plants and soil (Matti et al, 1975); (2) the accumulation and transfer of methylmercury in aquatic food chains (Blaylock et al., 1973; Huckabee et al., 1975, 1979); (3) the movement and distribution of inorganic and methylmercury in small streams (Huckabee and Blaylock, 1973); and (4) model development and validation of the behavior of methylmercury in a freshwater pond (Huckabee and Goldstein, 1975).

Early studies included measurement of mercury in the local east Tennessee environment. The use of mosses as indicators of airborne mercury pollution (Huckabee, 1973; Huckabee and Janzen, 1975) and the establishment of background levels of methylmercury in fish from the Great Smoky Mountains National Park (Huckabee et al., 1974) were two of the earlier studies.

As a result of our demonstrated expertise in environmental mercury research, investigators from the Environmental Sciences Division became involved with the state of Virginia, the state of Tennessee, and the Tennessee Valley Authority in establishing the mercury inputs to the Holston River-Cherokee Reservoir system from the chloralkali plant located in Saltville, Virginia (Hildebrand et al., 1980a). Several publications resulted from this study and include: "Behavior and Transport of Mercury in a River-Reservoir System Downstream of an Inactive Chloride Plant" (Turner and Lindberg, 1978), "Distribution and Bioaccumulation of Mercury in Biotic and Abiotic Compartments of a Contaminated River-Reservoir System" (Hildebrand et al., 1976), and "Mercury Accumulation in Fish and Invertebrates of the North Fork Holston River, Virginia and Tennessee" (Hildebrand et al., 1980c).

More recent studies conducted by the Environmental Sciences Division have focused on atmospheric mercury releases to the environment. These studies include atmospheric releases from contaminated soils (Lindberg et al., 1979), from chlorine production solid waste deposits (Lindberg and Turner, 1977), and from power plants (Lindberg, 1980).

Mercury studies by members of the Environmental Sciences Division were not limited to the United States. The Environmental Sciences Division was involved through the U.S. Department of State in an ecological study of the distribution of mercury in the environment in the vicinity of mercury mines in Almaden, Spain (Hildebrand et al., 1980b). The Almaden mining operations have generated the oldest and possibly the most extensive case of mercury effluents in the world. The study, which was initiated in 1974 and completed in 1977, was conducted in both terrestrial and aquatic systems with the objective of defining the range of mercury concentrations in ecosystem compartments and determining the distribution of mercury in these compartments with distance from the mining area. The research was funded by the National Science Foundation Office of International Programs, in accordance with agreements for scientific collaboration between the United States and Spain. The study was a joint effort with Spanish investigators at the mining operations, the Environmental Protection Agency (EPA), and the Environmental Sciences Division at ORNL. Staff members from the Environmental Sciences Division spent several months in Almaden while directing, conducting, and coordinating the research. Mercury analyses were conducted in Spain and at ORNL. Expertise from the Analytical Chemistry Division at ORNL was also provided to help establish procedures for mercury analyses in Spain. Several publications (Hildebrand et al., 1980b; and Huckabee et al., 1983; Lindberg et al., 1979) which resulted from this study enhanced the reputation of the Environmental Sciences Division as a recognized center of expertise for mercury pollution research.

Additional studies on mercury and other trace contaminants that reinforce the Environmental Sciences Division's activities in pollution studies have not been included in this brief summary. Our aim is to establish for the record that the Environmental Sciences Division has been involved in mercury research, especially that dealing with its behavior in freshwater environments, including uptake and accumulation by fish and other aquatic organisms, for many years.

D. ENVIRONMENTAL SURVEILLANCE, MONITORING, AND REPORTING

Monitoring of radioactive and chemical effluents, both gaseous and liquid, is conducted at each of the Oak Ridge installations. Starting in 1971, data from ORGDP, ORNL, and Y-12 have been compiled in an annual Environmental Monitoring Report for the Oak Ridge facilities. The measured effluents are compared to applicable standards and are intended to inform the reader of the effectiveness of the pollution control program at each of the Oak Ridge facilities. The report is distributed to EPA, Tennessee State Health Department, Oak Ridge Department of Public Health, and local news media.

EARLY ACTIVITIES (Y-12, ORGDP)

Mercury concentrations in the Y-12 effluents to the East Fork of Poplar Creek were measured at the Y-12 Plant starting in 1954, and quarterly averages have been recorded since that time. It is to be noted (Fig. 1) that the mercury concentrations were significantly higher during the period 1955-1959 than at any other time and that the majority of the mercury was discharged to East Fork Poplar Creek during the period mid-1956 to 1959. Our current estimate of the discharge over the years is now about one-half of what we estimated it to be in 1977 (239,000 vs 470,000 lb).

In 1970, Merwyn Sanders, the Y-12 Environmental Coordinator, initiated a survey to determine the mercury content in fish, water, and sediment samples from various parts of the Oak Ridge area. These results were reported to J. D. McLendon in an internal memorandum dated August 6, 1970 (see Appendix 4).

Following is a summarization of the findings of this survey:

- Twenty-one fish were caught from New Hope Pond, East Fork Poplar Creek, and Bear Creek.

- Ten of the fish exceeded the U.S. Public Health Service 1970 limit of 0.5 ppm.

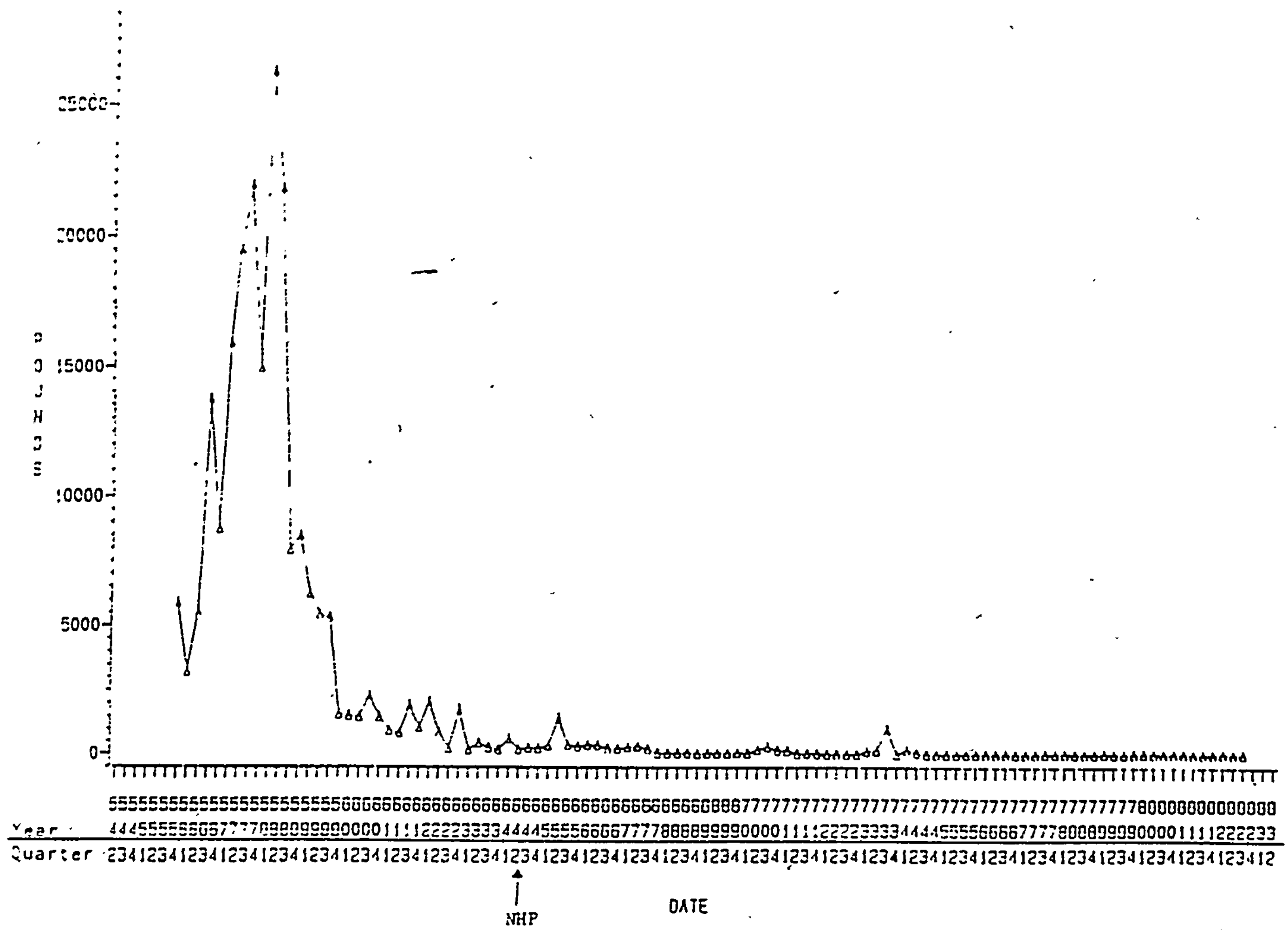


Fig. 1. Mercury losses to East Fork Poplar Creek, fourth quarter 1955 through third quarter 1982.

- Five fish were purchased at an Oak Ridge market and two from the Y-12 cafeteria, levels ranged from 0.03 to 0.67 ppm, average was 0.203 ppm.

- The average concentration of the twenty-one fish was 0.48 ppm and the highest was 1.3 ppm.

- Twelve water samples were taken in New Hope Pond, East Fork Poplar Creek, Bear Creek, and Melton Hill Lake. A maximum concentration of 0.0005 ppm was reported.

- Ten mud samples were taken in New Hope Pond, East Fork Poplar Creek, Bear Creek, and Melton Hill. A maximum concentration of 63 ppm was reported.

Data from the measurement of mercury in the effluent from New Hope Pond have been included in the annual Environmental Monitoring Report of the Oak Ridge facilities since the report was first issued in 1971. Table 3 provides a compilation of the data taken from these reports for the years 1971-1982.

A sediment sampling program was initiated by ORGDP in 1975 to determine the concentrations of various metals in Poplar Creek. Samples are collected twice annually and analyzed for various metals, one of which is mercury. These data have been included in the annual Environmental Monitoring Report since that time (see Table 4).

AQUATIC MONITORING PROGRAM FOR ENVIRONMENTAL ASSESSMENT (Y-12, ORNL, CARL, AND ORGDP FACILITIES) 1974-1975

In the early part of 1974, the Atomic Energy Commission (AEC) decided that information should be compiled on the Oak Ridge facilities [Y-12, ORNL, Comparative Animal Research Laboratory (CARL), and Oak Ridge Gaseous Diffusion Plant (ORGDP)] for an environmental assessment to provide a basis for judging whether an environmental impact statement should be prepared for these facilities. The Environmental Sciences Division was requested to provide information for this document and to conduct a short-term aquatic surveillance program (ERDA, 1975, Vol. VI) to supplement the available data that would be used to describe the aquatic systems identified as possible

Table 3. Water quality data - East Fork Poplar Creek. Mercury concentrations in New Hope Pond discharges (Y-12) reported in annual environmental monitoring reports[a]

	Concentration (mg/L)[b]		
Year	Maximum	Minimum	Average
1971	0.007	0.0005	0.003
1972	0.0009	<0.0005	<0.0006
1973	0.001	0.0003	0.0005
1974	<0.0005	<0.0005	<0.0005
1975	0.0009	<0.0005	<0.0006
1976	0.0008	<0.0005	<0.0005
1977	0.003	<0.0005	<0.002
1978	0.002	<0.0005	<0.001
1979	0.004	<0.001	<0.002
1980	0.003	<0.001	<0.002
1981	0.002	<0.001	<0.002
1982	0.007	<0.001	<0.002

[a]Environmental monitoring reports, (United States Atomic Energy Commission 1971–1973, United States Energy Research and Development Administration 1974–1976, United States Department of Energy 1977–1982) Oak Ridge Facilities.

[b]Monthly composite samples are analyzed. The annual values are based on an average of the results of the monthly analyses.

Table 4. Sediment data (dry weight basis)[a]
Mercury (µg/g)

Location[b]	1976	1977	1978	1979	1980	1981	1982
CS-1	<0.5	0.3	<0.2	<0.2	4	1	3
PS-2	2	26.6	7	35	4	6	
PS-3	11	11.9					
PS-4	2	12.2					
PS-5	8	—1.4	2	<0.3	5	4	
PS-6	8	39	8	11	12	10	10
PS-7	68	1.8					
PS-8	1	1.6					
PS-9	10	11	2	3	5	3	
PS-10	<3	2.7	17	3	19	10	19
PS-11	<5	4.6					
PS-12	3	<2.9	6	<9	6	6	
PS-13	50	3.3					
PS-14	2	153.6					
PS-15	2	4.0	21	6	4	10	
PS-16	3	11.3					
PS-17	1	9.6	<2	<13	11	3	9
PS-18		20.4	5	4	10	6	9
PS-19		41.9	14	21	14	9	8
PS-21			6	<1	4	2	51
PS-22			3	7	13	96	
CS-20		0.4	<0.2	<0.2	1	3	3

[a]Average of two samples collected annually.

[b]Figure 9 - 1977 Environmental Monitoring Report.

areas of impact. It was realized that the data from this short-term survey would not be sufficient to assess the impact of the Oak Ridge facilities on aquatic biota (ERDA, 1975, Vol. VI), but they would aid in developing a more comprehensive monitoring program for impact analyses.

The survey was initiated in August of 1974 and continued through March of 1975. Locations of the sampling stations are given in ERDA (1975, Vol VI). Data from the survey were used along with routine monitoring data for the facilities and other information to publish a "Preliminary Draft Environmental Analysis, Oak Ridge Operations" (ERDA, 1975). Sediment analyses for mercury from the East Fork Poplar Creek and tissue analyses of fish from Poplar Creek were included in the report. It was stated on page 73 of Volume VII (ERDA, 1975) of the Preliminary Draft Environmental Analysis that preliminary analyses of tissue from fish collected in Poplar Creek showed mercury levels as high as 0.5 μg/g in bluegill and 2.0 μg/g in carp. These levels equaled or exceeded the then action level of 0.5 μg/g for commercial fish, as set by the U.S. Food and Drug Administration, which was subsequently changed to the present action level of 1.0 μg/g. It was also stated on page 73 of Volume VII (ERDA, 1975) that excessive mercury levels would preclude the use of Poplar Creek for fishing, both recreational and commercial.

The "Preliminary Draft Environmental Analysis, Oak Ridge Operations" (ERDA, 1975) was submitted to ERDA/ORO, along with a proposed sampling program (and a summary of the estimated cost), indicating that the monitoring program was needed to upgrade the analysis to the status of a draft environmental impact statement (Appendix 2, letter from R. F. Hibbs to R. J. Hart, December 1975). Circumstances evolving from this draft report and the proposed monitoring program played a role in the request that culminated in the Report on Mercury Contamination in Poplar Creek and the Clinch River (Elwood, 1977) (Appendix 3).

1977 UCC-ND MONITORING ACTIVITIES

The annual monitoring reports for the DOE-Oak Ridge Facilities were formal documents which were given state and local distribution.

The following is a quote from the 1977 Environmental Monitoring Report (Y/UB-8) with regard to the mercury in fish study which was conducted in 1976 and 1977:

"As a result of higher than background mercury concentrations in creek sediments and known use of large quantities of mercury at the Y-12 Plant until 1963, a fish study in Poplar Creek and the Clinch River was undertaken in 1976 and 1977 to determine the significance of these findings. Both migratory and nonmigratory fish, including edible and rough species, were studied.

During 1976 and 1977, 649 fish were analyzed. Sixty-two edible fish from this group contained mercury concentrations exceeding the proposed Food and Drug Administration (FDA) action level of 0.5 μg/g. Representative of average concentrations in fish taken from Poplar Creek near ORGDP are largemouth bass 0.72 μg/g, bluegill 0.42 μg/g, and crappie 0.23 μg/g. Fish taken from the Clinch River near Poplar Creek showed average concentrations in largemouth bass of 0.38 μg/g, bluegill 0.15 μg/g, and crappie 0.14 μg/g.

While these mercury concentrations are higher than background measurements made from Melton Hill Reservoir fish (bass <0.02, bluegill <0.04, crappie 0.03), they do not constitute a toxicity hazard. The FDA proposed action level (proposed in December 1974) does not apply to individual fish, rather to averages, in order to control total mercury consumption. The action level is based on a consumption rate three times the national average plus an additional safety factor of ten as well. An overall safety factor of 30 results. Thus, while some of the fish taken in the vicinity of ORGDP exceeded the proposed action level, an extraordinarily high and protracted consumption rate of these fish would be needed in order to reach levels of concern."

The analysis of mercury in fish collected from the Clinch River was made a part of the ORNL monitoring program in 1978 and data from these measurements have been included in the Environmental Monitoring Reports beginning in 1978.

1977 ENVIRONMENTAL SCIENCES DIVISION REPORT ON MERCURY CONTAMINATION IN POPLAR CREEK AND THE CLINCH RIVER

In early 1976 (April or May), the Environmental Sciences Division (ESD) was requested to assist in the design and implementation of a study to determine the mercury concentration in fish in the vicinity of the Oak Ridge Gaseous Diffusion Plant (ORGDP). The request for ESD participation in the study and in preparing a report on the results was made at a meeting at the Y-12 Plant attended by staff from DOE/ORO (J. F. Wing, W. Hibbitts), UCC-ND (R. G. Jordan, H. H. Abee), ORGDP (M. E. Mitchell), Y-12 (M. Sanders), and ORNL/ESD (J. W. Elwood, L. D. Eyman).

Mitchell from the Environmental Management Department at ORGDP explained why they wanted the study done. The ORGDP staff was concerned that the elevated mercury level in the lower portion of Poplar Creek was coming from ORGDP. They wanted to know (1) if fish in the vicinity of ORGDP were contaminated with mercury, (2) if the contamination had spread into the Clinch River downstream of ORGDP, and (3) the source of the contamination (i.e., whether the mercury in Poplar Creek was from upstream sources, from ORGDP discharges, or both). Elwood and Eyman recommended sampling fish in the Clinch River, in Poplar Creek upstream and downstream of ORGDP, and in East Fork Poplar Creek. Sampling in East Fork Poplar Creek, which enters Poplar Creek just upstream of ORGDP, was recommended for two reasons. First, we were aware of local monitoring data showing elevated mercury levels in sediments (memorandum from Sanders to McLendon, August 1970, Appendix 4; Reece, 1974) and fish (memorandum from Sanders to McLendon, August 1970, Appendix 4) from this stream. Second, we were aware of mercury losses that had occurred at Y-12. Thus, in designing the fish sampling, our staff members considered the possibility that the mercury in sediments in the lower portion of Poplar Creek was coming from East Fork Poplar Creek. Subsequently, it was decided that the proposed sampling for this study would be limited solely to Poplar Creek and the Clinch River.

The 1976-1977 study did show significant mercury contamination of fish but did not identify the source(s) of mercury in Poplar Creek (Elwood, 1977). Analysis of unpublished data on mercury in East Fork Poplar Creek, which is contained in Elwood (1977), did suggest East Fork Poplar Creek as a likely source of mercury in Poplar Creek and the Clinch River. This suggestion is reflected in the recommendations contained in Elwood's (1977) report.

Subsequent to publication of the report, laboratory management was advised of the importance of and need for carrying out these recommendations (Appendix 4). The Abstract, Introduction, Recommendations, and Distribution List from the Elwood (1977) report are included as Appendix 3. Six memoranda relating to this report are included as Appendix 4.

INTERACTIONS WITH TVA

On May 4, 1977, two members of the DOE (then ERDA) Environmental Protection Branch and a member of the UCC-ND HSEA staff met with representatives of TVA's Division of Environmental Planning at TVA's offices in Chattanooga to provide TVA with the raw data then available on mercury in Poplar Creek and Clinch River fish. The group requested that TVA make a comparative assessment of the data with the TVA ongoing program for measuring mercury in fish in all of its reservoirs, and suggested that TVA consider incorporating these waters in their ongoing monitoring program. A positive interest was expressed in the suggestion, but it was indicated that internal discussions and budget review would be required before a decision on the matter could be reached.

Subsequent correspondence from TVA (letter from Brooks to Hart, dated August 2, 1977) to DOE (ERDA) indicated an agreement to design and implement a sampling survey in the Melton Hill Reservoir/Clinch River area in the vicinity of ORNL; however, later correspondence (letter from Brooks to Hart, dated March 27, 1978) stated that after a review of the rather extensive data base sent to them, they saw no need to collect any additional samples in Calendar Year 1978 and suggested that the situation be reappraised in January 1979 to determine the need for additional sampling.

ESD CONCERNS OVER MONITORING OF AQUATIC ENVIRONMENTS AT DOE-OAK RIDGE FACILITIES

During the course of the 1977 study of mercury contamination in Poplar Creek and the Clinch River, the ESD staff members involved reviewed available monitoring reports for DOE-Oak Ridge facilities to locate mercury data. They found a lack of data on mercury in fish or other biota, problems in interpreting the sediment mercury data in these reports, and problems with some of the procedures and methods used in monitoring for mercury. For example, in attempting to interpret mercury levels in sediments collected in the vicinity of one of the DOE-Oak Ridge facilities (ORGDP), they found that the limited distribution of sampling locations, the lack of data on mercury in effluents, and the lack of information on sediment particle size precluded our distinguishing among variations in mercury levels due to (1) differences in mercury discharges from this facility, (2) differences in mercury transport from DOE facilities upstream, and (3) textural differences in the sediment samples. As a result of these problems in the monitoring program, the data were inadequate for identifying the source(s) of the mercury or for assessing the trends in mercury levels in the area of this DOE-Oak Ridge facility (ORGDP). Our questions about the monitoring programs were reflected in the recommendations in the Elwood (1977) report just described and were further elaborated in a memorandum dated September 9, 1977, from S. I. Auerbach to C. R. Richmond, Associate Director for Biomedical and Environmental Sciences at ORNL. A copy of this memorandum is included in Appendix 4.

ECOLOGICAL STUDIES FOR THE ENVIRONMENTAL ANALYSES OF ORGDP AND ORNL FACILITIES

In 1976, ERDA/ORO decided that an impact statement should be prepared on the operation of the Oak Ridge Gaseous Diffusion Plant (ORGDP). Staff in the Environmental Sciences Division (ESD) were to be responsible for assessing the impacts of ORGDP operations on the aquatic and terrestrial environs. A decision was made that insufficient ecological data were available for this assessment and that additional studies should be conducted. The justification and need for such a baseline ecological survey were provided in a previous report related to operation of all the Oak Ridge facilities (ERDA, 1975). A sampling program was designed by ESD staff and submitted to ERDA/ORO for approval in January 1977 (letter from Auerbach to Wing dated January 1977, see Appendix 5). Sampling was initiated in April 1977 and continued through September 1978. A portion of this sampling program consisted of collection of fish from Clinch River and Poplar Creek sites above and below ORGDP for trace element analyses, including mercury. No sampling was conducted in East Fork Poplar Creek. Data from the baseline ecological survey were used to prepare an environmental assessment (not an environmental impact statement) which was published in December 1979 (DOE, 1979; see Appendix 5 of this testimony for title page and table of contents). All of these data, including the information on mercury concentrations in fish, water, and sediments in the vicinity of ORGDP, were later published in a separate report (Loar, 1981; see Appendix 5 for title page, table of contents, and distribution list).

Similar procedures and rationale were followed for evaluating the impacts of operation of Oak Ridge National Laboratory. A sampling program similar to the ORGDP survey was submitted for ERDA/ORO approval in March 1977 (letter from Auerbach to Wing dated March 1977; see Appendix 5). Sampling was initiated in March 1979 and continued through June 1980. Mercury concentrations were analyzed in fish collected from the White Oak Creek watershed and the Clinch River.

These and other ecological data were published in a report (Loar et al., 1981; see Appendix 5 for title page, table of contents, and distribution list) that provided a basis for an evaluation of the impacts of ORNL operations on the aquatic environs. This evaluation (or environmental analysis), which was not an environmental impact statement, was published in November 1982 (Boyle et al., 1982; see Appendix 5 for title page, table of contents, and distribution list).

ACTIVITIES IN 1982 AND 1983

Starting in April 1982 and continuing through the present, the Environmental Sciences Division has been involved in a number of activities for the Y-12 Plant related to the mercury contamination problem. The purpose of this section is to briefly highlight these activities. Supporting material is included in appendices.

Study to Determine Mercury Concentrations in East Fork Poplar Creek and Bear Creek in 1982

The Health, Safety, and Environmental Affairs Division at the Y-12 Plant requested the services of the Environmental Sciences Division in April 1982 to determine mercury concentrations in East Fork Poplar Creek and Bear Creek. The objectives of this study and assignment of responsibilities are summarized in an internal correspondence memorandum dated May 4, 1982 (See Appendix 6). We did not consider this short-term study in 1982 to represent a full implementation of the 1977 recommendations (Elwood, 1977) because of the limited scope and time frame of the study. The study was given high priority by both Y-12 and the Environmental Sciences Division and, as a result, the study was completed within a month and a draft report prepared for review before the end of May 1982. Van Winkle presented a briefing for Y-12 Plant Management on June 2, 1982 (see Appendix 7). The draft report received technical review by staff in the Environmental Sciences Division and the Health and Safety Research Division at ORNL and in the Health, Safety, and Environmental Affairs Division at Y-12. After technical approval by the appropriate managers at ORNL and Y-12, the final report was published on September 7, 1982. The Abstract, Introduction, Conclusions, Recommendations, and Distribution List from this report are included in this testimony as Appendix 8.

Mercury Concentrations in Fish
in the Vicinity of ORGDP in 1982

At the same time we were performing the May 1982 study for Y-12, M. Mitchell, Head of the Environmental Management Department at ORGDP, requested the services of the Environmental Sciences Division in collecting fish upstream and downstream of ORGDP in Poplar Creek. The analyses were completed in October 1982 (see Appendix 9), but the results have not been interpreted or included in any report.

Survey of Drainage at Y-12

Results of the 1982 study (Van Winkle et al., 1982) confirmed that the Y-12 Plant area was still an active source of mercury to East Fork Poplar Creek. These results led immediately to discussion and design of further surveys for mercury contamination in drainage waters within the Y-12 Plant and investigations of the mass balance of mercury in New Hope Pond. The objective of these latter studies was to identify and characterize current sources of mercury entering East Fork Poplar Creek (see Appendix 10). The first phase of these additional studies was completed in fall 1982. Specific sources of mercury contamination were identified and a remedial action plan was developed and implemented to clean up these sources. Studies to further define the problem and to assess the effectiveness of clean-up measures are in progress. A draft interim report has been prepared by R. R. Turner of the Environmental Sciences Division and is currently undergoing technical review.

Mercury Concentrations in Hair and Other Tissues from Cows and Horses

Following up on Recommendation 3 in Van Winkle et al. (1982, p. 54) and in light of comments received during the review of this report (Appendix 11), hair samples were obtained in August 1982 from cows and horses, some of which were controls and some of which had been grazing on pasture grass in the contaminated floodplain of East Fork Poplar Creek and drinking water out of this creek. The rationale for sampling hair for mercury analysis is that mercury contamination of mammals, resulting from the consumption of contaminated food and water, is reflected in elevated levels of mercury in the hair of these animals. Due to suspected contamination of one of the hair samples during the chemical analysis, additional hair samples were obtained in November 1982. In addition, since one of the two cows sampled in November 1982 was being slaughtered for beef, samples of various other tissues (muscle, liver, and brain) were obtained for mercury analysis. These samples have been analyzed for total mercury, and preliminary results indicate no significant mercury contamination in the various tissues.

Literature Survey of Population Density Data for Selected Species of Sport Fish in Streams, Reservoirs, and Lakes

On October 18, 1982, G. J. Marciante, Environmental Protection Branch, Oak Ridge Operations Office, phoned J. W. Elwood regarding the feasibility of estimating the size of the bluegill population in East Fork Poplar Creek. Elwood suggested that quantitative estimates of the population at four or five locations could be obtained within a two-week period. Discussion, however, led to a more limited request from the Health, Safety, and Environmental Affairs Division at Y-12 to perform a literature survey. The report prepared by J. W. Elwood was transmitted to Y-12 with a cover memorandum dated November 9 (see Appendix 12).

E. NEED FOR ADDITIONAL STUDIES AND MONITORING OF MERCURY IN THE VICINITY OF THE DEPARTMENT OF ENERGY FACILITIES IN OAK RIDGE

Based upon experience to date, there appear to be a need for additional studies and monitoring of mercury in the Oak Ridge environs. We suggest it is necessary (1) to determine the spatial extent and magnitude of the mercury contamination, (2) to identify the active and residual sources of mercury, and (3) to determine the changes in the level of contamination over time.

We suggest as a first step that the spatial extent and magnitude of mercury concentrations in the streams and reservoirs downstream of the three DOE facilities in Oak Ridge be determined from measurements of mercury in surface and subsurface sediments, and some work has already been initiated. Sediments are reliable indicators of mercury contamination because the bulk of the mercury in contaminated streams and lakes is associated with sediments and the background level of mercury in sediments is well documented. Sediment surveys must be carried out with due regard for the effect of sediment particle size distribution on mercury concentration. Most of the past surveys around the Oak Ridge facilities have neglected to consider particle size and, thus, much of the historical data cannot be fully interpreted.

To document the spatial extent of contamination from the Y-12 Plant, we suggest that sediment sampling extend from the Y-12 discharge into New Hope Pond downstream into the Clinch River (Watts Bar Reservoir), at least to its confluence with the Emory River near Kingston, Tennessee. A survey of mercury in sediments will provide information on (1) how far downstream of the three DOE facilities in Oak Ridge the mercury contamination has spread, (2) the level of contamination of surface sediments from which biological organisms (e.g., fish) can accumulate mercury, (3) current levels of mercury in sediments at reference sites that can be sampled over time to establish temporal trends in mercury concentrations throughout the area, and (4) the location of any sizeable quantities of sediment-bound mercury that may need to be removed from streams because of the biological availability of the mercury to aquatic organisms and/or because of the susceptibility of the contaminated sediments to resuspension and transport, resulting in the downstream spread of contamination.

Regular sampling of mercury in sediments can also assist in identifying active sources of mercury discharges. Such a study would provide an inventory of the mercury associated with sediments in East Fork Poplar Creek, the stream in which mercury contamination appears to be most severe. Such an inventory is essential for assessing the role of residual mercury in subsurface sediments of East Fork Poplar Creek, derived from past releases, in sustaining surface sediment contamination. Based on an analysis of the current discharge of mercury from New Hope Pond and on the observed pattern of mercury concentrations in sediments and fish in East Fork Poplar Creek downstream of this pond in 1982, it is suggested that the current concentrations in surface sediments in East Fork Poplar Creek can be explained by the current discharge of mercury (about 1 to 2 oz/day) from the Y-12 Plant area. Resolution of the issue of the importance of past versus current mercury releases is germane to planning actions for reducing the mercury contamination in surface waters.

A study should also be conducted of mercury concentrations in the floodplain of East Fork Poplar Creek. This floodplain, portions of which are known to contain mercury above background levels, is contiguous with residential areas and recreational facilities in the City of Oak Ridge, and commercial and residential development adjacent to the floodplain is increasing. In addition, the floodplain is used for grazing a few cattle and horses. At least one family obtains its beef from cattle that graze on this floodplain and that drink water from East Fork Poplar Creek. One cow sampled from this area showed no significant mercury contamination in edible tissues. We suggest that this area be sampled to determine the level of mercury in soil and grasses on the floodplain, in air above the floodplain, and in hair of livestock (horses, cattle) grazing on the floodplain. Because of the possibility that mercury-contaminated sediments dredged from East Fork

Poplar Creek have been used in gardens, studies should also be conducted to determine the concentration of mercury in vegetables grown in these soils.

Finally, we suggest that a regular biological sampling program be initiated to determine the level of mercury in fish and other edible aquatic organisms in local streams and reservoirs. Such sampling should be done on a regular basis at selected sites, including uncontaminated tributaries, to establish temporal trends in mercury levels of aquatic organisms consumed by humans. We also suggest that a study be conducted to measure the density of sport fish in East Fork Poplar Creek where mercury levels in fish from the upper portions of the drainage currently exceed the FDA action level for mercury of 1.0 ppm (Appendix 12). Such a study would provide information on the number of catchable fish available to sport fishermen, and hence, the potential public health risk from the consumption of fish from this stream. This study would also provide baseline data on both mercury levels in fish and density of fish for comparison with data collected after the new sewage treatment plant on East Fork Poplar Creek begins operation. The operation of this sewage treatment plant is expected to significantly improve water quality in the stream. When this occurs, fish populations that are currently limited by poor water quality due to discharges from the old sewage treatment plant are likely to increase. This could, in turn, result in increased harvest of sport fish from East Fork Poplar Creek.

We suggest that results, including discussion, interpretation, and conclusions, from all subsequent studies and monitoring of mercury (and other contaminants) in the vicinity of the DOE facilities in Oak Ridge be published in a form useful to the public and the scientific community.

F. REFERENCES

Blaylock, B. G., E. H. Curtis, R. A. Goldstein, J. W. Huckabee, Carol S. Matti, Susan L. Perryman, and J. P. Witherspoon. 1973. Ecology of toxic metals. pp. 140-175. IN W. Fulkerson, W. D. Shults, and R. I. Van Hook (eds.), Ecology and Analysis of Trace Contaminants, Progress Report - January 1973-September 1973. ORNL/NSF/EATC-6. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Blaylock, B. G., J. M. Loar, J. Stokely, T. G. Scott, M. Ferguson, and J. H. Stewart. 1983. Preliminary report of the concentrations of mercury, PCBs, and uranium in aquatic organisms from upper East Fork Poplar Creek and environs. Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee (unpublished report).

Boyle, J. W., et al. 1982. Environmental analysis of the operation of Oak Ridge National Laboratory (X-10 site). ORNL-5870. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Department of Energy (DOE). 1979. Environmental Assessment of the Oak Ridge Gaseous Diffusion Plant Site. DOE/EA-0106. Department of Energy, Oak Ridge, Tennessee.

Elwood, J. W. 1977. Mercury contamination in Poplar Creek and the Clinch River. ORNL/CF-77/320. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Energy Research and Development Administration (ERDA). 1975. Preliminary Draft Environmental Analysis, Oak Ridge Operations, Vols. VI and VII. ERDA, Oak Ridge, Tennessee.

Federal Register. 1979. Action level for mercury in fish, shellfish, crustaceans, and other aquatic animals. Fed. Regist. 44(14):3990-3993.

Gerstner, H. B., and J. E. Huff. 1977. Clinical toxicology of mercury. J. Toxicol. Environ. Health 2:491-526.

Goldwater, I. J. 1971. Mercury in the environment. Sci. Am. 224:15.

Hildebrand, S. G., A. W. Andren, and J. W. Huckabee. 1976. Distribution and bioaccumulation of mercury in biotic and abiotic compartments of a contaminated river-reservoir system. pp. 211-232. IN R. W. Andrew, P. V. Hodson, and D. E. Konasewich (eds.), Toxicity to Biota of Metal Forms in Natural Waters. Standing Committee on the Scientific Basis for Water Quality Criteria of the International Joint Commission's Research Advisory Board.

Hildebrand, S. G., S. E. Lindberg, R. R. Turner, J. W. Huckabee, R. H. Strand, J. R. Lund, and A. W. Andren. 1980a. Biogeochemistry of mercury in a river-reservoir system: Impact of an inactive chloralkali plant on the Holston River - Cherokee Reservoir, Virginia and Tennessee. ORNL/TM-6141. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 163 pp.

Hildebrand, S. G., J. W. Huckabee, F. S. Diaz, S. A. Janzen, J. S. Solomon, and K. D. Kumar. 1980b. Distribution of mercury in the environment at Almaden, Spain. ORNL/TM-7446. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 98 pp.

Hildebrand, S. G., R. H. Strand, and J. W. Huckabee. 1980c. Mercury accumulation in fish and invertebrates of the North Fork Holston River, Virginia and Tennessee. J. Environ. Qual. 9(3):393-400.

Huckabee, J. W. 1973. Mosses: Sensitive indicators of airborne mercury pollution. Atmos. Environ. 7:749-754.

Huckabee, J. W., and B. G. Blaylock. 1973. Transfer of mercury and cadmium from terrestrial to aquatic ecosystems. pp. 125-160. IN Sanat K. Dhar (ed.), Metal Ions in Biological Systems. Plenum Publishing Corp., New York.

Huckabee, J. W., and R. A. Goldstein. 1975. Dynamic redistribution of methylmercury in a pond ecosystem. pp. 626-638. IN Proc., 1st Annual National Science Foundation Trace Contaminants Conference. CONF-730802. National Technical Information Service, Springfield, Virginia.

Huckabee, J. W., and S. A. Janzen. 1975. Mercury in moss: Derived from the atmosphere or from the substrate? Chemosphere 1:55-60.

Huckabee, J. W., C. Feldman, and Y. Talmi. 1974. Mercury concentrations in fish from the Great Smoky Mountains National Park. Anal. Chim. Acta 70:41-47.

Huckabee, J. W., R. A. Goldstein, S. A. Janzen, and S. E. Woock. 1975. Methylmercury in a freshwater food chain. pp. 199-216. IN Institute for Environmental Studies, University of Toronto, International Conference on Heavy Metals in the Environment. Toronto, Ontario, Canada.

Huckabee, J. W., J. W. Elwood, and S. G. Hildebrand. 1979. Accumulation of mercury in freshwater biota. Chap. 12, pp. 277-302. IN J. O. Nriagu (ed.), The Biogeochemistry of Mercury in the Environment. Elsevier/North Holland Biomedical Press, Amsterdam.

Huckabee, J. W. , F. S. Diaz, J. Solomon, and A. Janzen. 1983. Distribution of mercury in vegetation at Almaden, Spain. Environ. Pollut. 30:211-224.

Lindberg, S. E. 1980. Some observations on the partitioning of mercury in a power plant plume and its removal from the atmosphere. Atmos. Environ. 14:227-231.

Lindberg, S. E., and R. R. Turner. 1977. Mercury emission from chlorine production solid waste deposits. Nature 268:133-136.

Lindberg, S. E., D. R. Jackson, J. W. Huckabee, S. A. Janzen, M. J. Levin, and J. R. Lund. 1979. Atmospheric emission and plant uptake of mercury from agricultural soils near the Almaden mercury mine. J. Environ. Qual. 8(4):572-578.

Loar, J. M. (ed.). 1981. Ecological Studies of the Biotic Communities in the Vicinity of the Oak Ridge Gaseous Diffusion Plant. ORNL/TM-6714. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 329 pp.

Loar, J. M., J. A. Solomon, and G. F. Cada. 1981. Technical Background Information for the ORNL Environmental and Safety Report, Volume 2: A Description of the Aquatic Ecology of White Oak Creek Watershed and the Clinch River below Melton Hill Dam. ORNL/TM-7509/V2. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 198 pp.

Matti, C. S., J. P. Witherspoon, and B. G. Blaylock. 1975. Cycling of mercury and cadmium in an old-field ecosystem during one growing season. ORNL/NSF/EATC-10. 75 pp.

Oak Ridge National Laboratory (ORNL). 1971. The environment and technology assessment progress report, June-December 1970. ORNL/NSF/EP-3. ORNL, Oak Ridge, Tennessee.

Reece, John. 1974. Preliminary aquatic survey of East Fork Poplar Creek and Bear Creek, 1974. Environmental Protection Branch, Safety and Environmental Control Division, Oak Ridge Operations, U. S. Atomic Energy Commission, Oak Ridge, Tennessee.

Stroud, R. H. 1977. Changing challenges in recreational fisheries. Sport Fish. Inst. 284:1-6.

Turner, R. R., and S. E. Lindberg. 1978. Behavior and transport of mercury in a river reservoir system downstream of an inactive chloralkali plant. Environ. Sci. Technol. 12(8):918-923.

Van Winkle, W., R. W. Counts, J. G. Dorsey, J. W. Elwood, V. W. Lowe, Jr., R. McElhaney, S. D. Schlotzhauer, F. G. Taylor, and R. R. Turner. 1982. Mercury contamination in East Fork Poplar Creek and Bear Creek. ORNL/CF-82/257. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

World Health Organization (WHO). 1976. Environmental Health Criteria 1. Mercury. WHO, Geneva.

EQUIVALENCIES
(for water)

1 ppm = 1 μg/g = 1 mg/L = 1 mg/kg

1 ppb = 1 ng/g = 1 μg/L = 1 μg/kg

1983 Standards, Criteria, and Guidelines for Mercury

Air:	Workplace	NIOSH	0.05	mg/m^3	TWA-8 h TLV
Air:	Workplace	ACGIH	0.15	mg/m^3	15 min STEL
Air:	Workplace	OSHA	0.10	mg/m^3	Ceiling value
Air:	Emissions	NESHAP	0.001	mg/m^3 or	2300 g/d/plant
Air:	Ambient	Fed. Reg.	0.001	mg/m^3	Public areas
Water:	Drinking	EPA	0.002 mg/L	(2.0 ppb)	
Water:	Domestic water supply	Tenn.	0.0002 mg/L	(0.2 ppb)	
Water:	Fish and wildlife	Tenn.	0.05	μg/L	(0.05 ppb)
Water:	Fish and Wildlife	EPA*	0.20	μg/L	(0.2 ppb)
Water:	Effluent discharge	Tenn.*	0.05	mg/L	(50 ppb daily conc.)
Urine:		Y-12	0.3	mg/L	(0.3 ppm)
Fish Flesh:	Edible	FDA	1.0	μg/g	(1.0 ppm)

*Not applicable to Y-12 East Fork Poplar Creek